US Army Corps
of Engineers

ALFRED COFRANCESCO

**AQUATIC PLANT CONTROL RESEARCH PROGRAM**

TECHNICAL REPORT A-88-9

# AQUATIC PLANT IDENTIFICATION AND HERBICIDE USE GUIDE

## VOLUME I: AQUATIC HERBICIDES AND APPLICATION EQUIPMENT


by

Howard E. Westerdahl and Kurt D. Getsinger, Editors

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631



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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*


Volume I provides information on the use and fate of US Environmental Protection Agency-approved and registered herbicides for managing nuisance aquatic vegetation in US Army Corps of Engineer projects and navigable waterways. These herbicides include acrolein, copper, 2,4-D, dicamba, dichlobenil, diquat, endothall, fluridone, glyphosate, and simazine. Information on adjuvant classification and use is provided. Site factors affecting herbicide selection, such as water body uses and constraints, water quality, and hydology, are discussed. The selection and calibration of herbicide application equipment, for use with liquid and granular formulations, is examined.

Volume II is a plant identification and herbicide susceptibility guide for nuisance floating, emersed, and submersed aquatic plants. Color plates, line drawings, plant and habitat descriptions, and distribution for over 50 species are included.


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| Adjuvants | Aquatic plant control | Herbicide fate |
| Application equipment | Aquatic plant management | Macrophytes |
| Aquatic herbicides | Aquatic plants | |

# PREFACE

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP) (Appropriation No. 96X3122, Construction General). The APCRP is sponsored by the US Army Corps of Engineers (USACE) and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). The USACE Technical Monitor for APCRP is Mr. E. Carl Brown.

The purpose of this document (presented in two volumes) is to provide guidance to Corps District and Project personnel on aquatic plant identification, herbicide susceptibility of selected aquatic plants, registered herbicide selection, herbicide use, and pertinent environmental considerations in the use of herbicides.

This volume of the guide provides information on the use and fate of US Environmental Protection Agency (USEPA)-approved and registered herbicides for managing nuisance aquatic vegetation in USACE projects and navigable waterways. Also discussed are site factors that affect herbicide selection, fate processes of herbicides in aquatic environments, and adjuvant selection, including application equipment and calibration procedures.

Volume II is a plant identification and herbicide susceptibility guide for nuisance floating, emersed, and submersed aquatic plants. A synopsis of each registered herbicide's label and toxicity to nontarget organisms is provided to assist in the selection process.

Dr. John Rodgers, Institute of Applied Science, North Texas State University, Denton, TX, prepared the sections on site factors affecting herbicide selection and fate in aquatic environments. Mr. Ron Hoeppel (formerly of WES, now with Naval Facilities Engineering Command in Point Hueneme, CA) provided assistance to Dr. Howard E. Westerdahl, WES, in compiling the summary label information on each herbicide and the reference materials listed in the appendixes. Dr. Kurt Getsinger, WES, prepared the adjuvant section. Mr. Richard Cromwell, University of Florida, Gainesville, FL, compiled the section on equipment selection and calibration. Appreciation is expressed for the assistance of the USEPA's Registration Division in providing copies of Section 18 and 24c permits (Appendix D) and the US Army Engineer District, Jacksonville, for information given in Appendixes E, F, and G.

The aquatic plant identification section was partially completed by Dr. Robert Mohlenbrock of Biotic Consultants, Inc. Supplemental photographs and amended plant descriptions were provided by Dr. Getsinger and Mr. W. Reed Green, WES, and the State of Florida Department of Natural Resources, Tallahassee, FL. The herbicide susceptibility section was prepared by Dr. Westerdahl.

The Principal Investigator for this study was Dr. Westerdahl, Aquatic Processes and Effects Group (APEG), Ecosystem Research and Simulation Division (ERSD), EL, under the direct supervision of Dr. Thomas L. Hart, Chief, APEG, and under the general supervision of Mr. Donald L. Robey, Chief, ERSD, and Dr. John Harrison, Chief, EL. Mr. J. Lewis Decell was Program Manager of APCRP. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory (ITL). Copy layout was accomplished by Ms. Betty Watson, ITL.

This document was reviewed for technical accuracy by the parent chemical companies of aquatic herbicides discussed herein. Appreciation is also expressed to the many experts in aquatic plant management operations and research who reviewed and provided comments on improving this guide.

COL Dwayne G. Lee, CE, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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# CONTENTS

# INTRODUCTION

This volume was prepared to provide Corps of Engineers personnel with information on the use of currently registered aquatic herbicides, including site factors, environmental fate, adjuvants, and application equipment. This volume should be used as a desk reference and is a companion to Volume II, "Aquatic Plants and Susceptibility to Herbicides."

Several other guides for herbicide use are available which may supplement information found in this guide:

- Herbicide Manual, by Gary W. Hansen, Floyd E. Oliver, and N. E. Otto, 1983 (1st ed.) (available from: US Department of the Interior Bureau of Reclamation, Denver, CO 80202).
- Herbicide Handbook, 1983 (5th ed.) (available from: Weed Science Society of America, 309 West Clark Street, Champaign, IL 61820) (updated at 5-year intervals).
- Weed Control Manual, published annually (available from: Ag Consultants, Inc., 37841 Euclid Avenue, Willoughby, OH 44094).

# PART I: AQUATIC HERBICIDES AND ADJUVANTS

# REGISTERED HERBICIDES - AQUATIC PLANTS

| AQUATIC PLANT \ HERBICIDE | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMERSED PLANTS** | | | | | | | | | | | | | | |
| Alligatorweed *Alternanthera philoxeroides* | | | | G | G | F | | | | | | G | G | |
| American lotus *Nelumbo lutea* | | | E | E | | E | | | G | G | F | | G | |
| Bulrush *Scirpus* spp. | | | E | E | | G | F | | | | | | E | |
| Cattail *Typha* spp. | | | G | G | F | G | G | | | | | G | E | |
| Common reed *Phragmites australis* | | | | | | | | | | | | | G | |
| Cutgrass *Leersia hexandra* | | | | | | | | | | | | G | | |
| Fragrant waterlily *Nymphaea odorata* | | | E | G | G | E | | | G | G | F | G | E | |
| Giant cutgrass *Zizaniopsis miliacea* | | | | | | | | | | | | G | E | |
| Giant foxtail *Setaria magna* | | | | | | | | | | | | | G | |
| Maidencane *Panicum hemitomon* | | | | | | | F | | | | | F | E | |
| Paragrass *Panicum purpurascens* | | | | | | | | | | | | G | E | |
| Pickerelweeds *Pontederia* spp. | | | G | G | G | | | | | | | | F | |
| Sawgrass *Cladium jamaicense* | | | | | | | | | | | | | G | |

NOTE: F = Fair, G = Good, and E = Excellent

| AQUATIC PLANT \ HERBICIDE | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMERSED PLANTS (Cont.)** | | | | | | | | | | | | | | |
| Smartweeds *Polygonum* spp. | | | G | G | E | G | F | | G | G | | F | F | |
| Southern watergrass *Hydrochloa caroliniensis* | | | | | | | | | | | | G | | |
| Spatterdock *Nuphar luteum* | | | E | G | G | G | | | G | G | F | G | E | |
| Torpedograss *Panicum repens* | | | | | | | | | | | | G | E | |
| Waterchestnut *Trapa natans* | | | G | | | | | | | | | | | |
| Water paspalum *Paspalum fluitans* | | | | | | | F | | | | | G | | |
| Water pennywort *Hydrocotyle umbellata* | | | G | G | G | | E | E | | | | | | |
| Water primrose *Ludwigia uruguayensis* | | | E | E | | F | F | | F | F | F | F | | |
| Watershield *Brasenia schreberi* | | | E | E | | E | F | F | G | G | F | G | | |
| Waterwillow *Justicia americana* | | | | E | | | F | | | | | G | | |
| **FLOATING PLANTS** | | | | | | | | | | | | | | |
| Duckweed *Lemna minor* | | | G | G | E | | E | E | F | | | E | | E |
| Giant duckweed *Spirodela polyrhiza* | | | G | G | E | | E | E | | | | G | | E |
| Mosquito fern *Azolla caroliniana* | | | F | F | | | G | G | | | | G | | |

NOTE: F = Fair, G = Good, and E = Excellent

| HERBICIDE / AQUATIC PLANT | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FLOATING PLANTS (Cont.)** | | | | | | | | | | | | | | |
| Salvinia *Salvinia rotundifolia* | | | | | | | E | E | F | | | G | | |
| Slender duckweed *Wolffiella floridana* | | | | | | | G | | | | | G | | G |
| Waterhyacinth *Eichhornia crassipes* | | | | E | E | | E | E | F | F | F | | F | |
| Waterlettuce *Pistia stratiotes* | | | F | | | | E | E | G | | | | G | |
| Watermeal *Wolffia columbiana* | | | | | | | G | | | | | F | | G |
| **SUBMERSED PLANTS** | | | | | | | | | | | | | | |
| Bladderworts *Utricularia* spp. | | | G | | | G | G | | | | | G | | |
| Coontail *Ceratophyllum demersum* | G | | F | F | | E | E | E | E | E | E | G | | G |
| Egeria *Egeria densa* | G | | | | | G | G | E | E | E | E | G | | |
| Elodea *Elodea canadensis* | G | | | | | E | E | E | | F | G | G | | |
| Eurasian watermilfoil *Myriophyllum spicatum* | | | E | E | | G | E | E | E | E | E | G | | G |
| Fanwort *Cabomba caroliniana* | | | F | F | | | G | E | E | E | E | G | | G |
| Horned pondweed *Zannichellia palustris* | G | | F | F | | E | | | E | E | E | F | | F |
| Hydrilla *Hydrilla verticillata* | F | G | | | | F | G | E | G | G | G | G | | |

NOTE: F = Fair, G = Good, and E = Excellent

| AQUATIC PLANT / HERBICIDE | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUBMERSED PLANT (Cont.) | | | | | | | | | | | | | | |
| Naiads *Najas* spp. | G | | F | | | E | E | E | E | E | E | G | | E |
| Parrotfeather *Myriophyllum aquaticum* | F | | E | E | E | F | E | E | E | E | E | | F | |
| Pondweeds *Potamogeton* spp. | G | | | | | E | G | G | E | E | E | G | | E |
| Water buttercup *Ranunculus aquatilis* | F | | | | | E | E | E | | F | | | | |
| Widgeongrass *Ruppia maritima* | F | | | | | E | G | E | F | F | F | | | |
| Wildcelery *Vallisneria americana* | G | | | | | F | F | F | | | F | | | G |

NOTE: F = Fair, G = Good, and E = Excellent

## AQUATIC PLANT SUSCEPTIBILITY TO HERBICIDES

### Acrolein

A. Chemical Name and Formulation:
Chemical name: 2-propenal
Formulation: MAGNACIDE HERBICIDE

B. Mode of Action: Acrolein is a contact herbicide. It causes plant cell disruption through destruction of vital enzyme systems in the plant cells.

C. Application: Dosage rates should be from 0.6 to 11 ℓ/cu m/sec (0.16 to 3 gal/cu ft/sec). Application time range is 0.5 to 48 hr. Repeated applications may be necessary at 2- to 3-week intervals. The acrolein must be injected beneath the water surface, using polyethylene tubing, to maintain it in a liquid state. Only nitrogen gas completely free of oxygen should be used. NOTE: Application equipment may be purchased from the herbicide manufacturer.*

D. Timing of Application: Apply when the target plants are no more than 15 cm (6 in.) long and the water temperature is greater than 20° C (68° F). Application may be made at lower temperatures; however, reaction time may be longer.

E. Application Rates: Acrolein should be applied at full strength, i.e., 92% acrolein, 0.78 kg active ingredient/ℓ (6.5 lb ai/gal).

F. Maximum Water Concentration: No tolerance has been established for acrolein in potable water. Treated irrigation water reaching crops must not exceed 15 mg/ℓ (ppm).

G. Use Restrictions: Acrolein must not be used where treated water flows or transfers to suspected sources of drinking water.

H. Waiting Period: Treated water should not be released to any fish-bearing waters, or where it will drain into them until 6 days after application.

I. Toxicological Data: Fish are killed when exposed to acrolein concentrations greater than 1 mg/ℓ (ppm).

J. Precautions:
- Acrolein must not be used where a fish kill cannot be tolerated.
- Acrolein volatilization causes eye irritation and tearing; therefore, care must be exercised to ensure its release below the water surface.
- Swimming should not be allowed in treated water until acrolein residues are nondetectable.

K. Field Instructions:
- A preventive maintenance program is recommended, consisting of a series of acrolein applications throughout the growing season so that aquatic plants are never allowed to exceed 15 cm (6 in.) in length.

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* A listing of herbicide manufacturers is provided as Appendix A.

L. Adjuvant Use: Use of adjuvants is not specified.

M. Application Techniques:

- Subsurface, uniform injection of acrolein into quiescent water throughout the infested area or an irrigation/drainage canal is required, following instructions provided by Magna Corporation.
- Subsequent retreatment should occur based upon rate of plant regrowth.

N. Antidote Information:

CALL A PHYSICIAN IMMEDIATELY!

- Internal: If the material has been swallowed, give two glasses of water and induce vomiting immediately by introducing finger into the throat. If inhaled, get victim into fresh air immediately and give artificial respiration if breathing has stopped.
- External: If spilled on the skin, remove all contaminated clothing and wash skin with soap and running water. If material gets into eyes, wash immediately with water for 15 minutes.

## Copper Complexes

A. Chemical Name and Formulations:
   Chemical name: Copper chelates
   Formulations:
   - CUTRINE-PLUS (9% Cu, ethanolamine complex, liquid)
     Also, CUTRINE-PLUS granular (3.7% Cu)
   - KOMEEN (8% Cu, ethylenediamine complex, liquid)
   - KOPLEX Same as above
   - K-TEA (8% Cu, triethanolamine complex, liquid)

B. Mode of Action: Copper complexes act as cell toxicants and are not subject to photolysis or volatilization.

C. Application: Liquid formulations are applied using a hand or power sprayer and a drip system. From a boat, liquids are injected below the water surface or through weighted hoses dragging along the bottom. Invert emulsions of KOMEEN should be injected below the water surface. Granular formulations are applied using a hand-operated or boat-mounted Gandy-type broadcast spreader.

D. Timing of Application: To obtain most effective results, apply before plants reach the water surface, preferably on a sunny day when the water temperature is above 15° C (60° F).

E. Application Rates: CUTRINE-PLUS should be applied at 0.4 to 1.0 mg/ℓ Cu (1.2-3.0 gal/acre-ft) (ppm) to control *Hydrilla* (3-hr contact time is required in lotic environments). KOMEEN, KOPLEX, and K-TEA are applied at 57 to 150 ℓ/ha (6 to 16 gal/acre) to control *Hydrilla*. (Recommended dose is based on site-specific water volume, not surface area.)

F. Maximum Water Concentration: Copper concentration should not exceed 1 mg/ℓ (potable water) by weight copper.

G. Use Restrictions:
   - Do not apply when water temperature is below 15° C (60° F); (Copper ions form insoluble copper hydroxides, phosphates, and carbonates in water with pH > 7.) (This does not apply when using chelated copper.)
   - Currently, there are no restrictions on the use of treated water immediately following treatment.
   - Some states require a permit when CUTRINE-PLUS is used in public water. This would apply to any copper product or herbicide.

H. Waiting Period: Effect on target species can be observed in 7 to 10 days after treatment (CUTRINE-PLUS); 3 to 6 days, with full effects manifested in 4 to 6 weeks (KOMEEN/KOPLEX).

I. Toxicological Data:

| Species | Chemical | Hardness* (mg/ℓ as $CaCO_3$) | Exposure Period hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|---|
| Cutthroat trout | Copper chloride | 18-205 | 96 | 15.7-367 |
| Rainbow trout | Copper chloride | 42-194 | 96 | 57-574 |
| White perch | Copper nitrate | 53 | 96 | 6,200 |
| Striped bass | Copper nitrate | 53-55 | 96 | 4,000-4,300 |
| Bluegill sunfish | Copper chloride | 43 | 96 | 1,250 |
| Largemouth bass | Copper nitrate | 100 | 96 | 6,970 |

* In soft or acid water, trout and certain other species of fish may be killed at recommended treatment rates.

J. Precautions:
- Water hardness must be considered prior to treatments.
- Should not be used where pH of water or spray environment is below 6, because of copper ion formation and subsequent toxicity to fish.
- Contact with skin and eyes may be irritating.

K. Field Instructions:
- Effect of treatment will be observed within 4 to 6 weeks. In heavily infested areas, a second application after 12 weeks may be necessary.

L. Adjuvant Use:
- For spraying *Hydrilla*, Nalquatic polymer is a recommended adjuvant with KOMEEN. (Both KOMEEN and KOPLEX can be inverted with an adjuvant or used in combination with diquat.)
- When KOMEEN is applied as an invert emulsion, xylene and an emulsifying agent are normally used.

M. Application Techniques:
- Apply chemical uniformly over the surface area of infested area.
- Treat from shoreline outward toward the center of the water body, preventing entrapment of fish within the treated area.
- In heavily infested, smaller water bodies, treat only one third to one half of the area at a time; allow 1 to 2 weeks between successive treatments.

- Apply with hand or power sprayer, drip system, or any other method to provide even distribution over the treatment area. (See label recommendations.)

N. Antidote Information:

- Thoroughly wash contaminated skin and eyes.
- If swallowed, call a doctor.
- Since KOMEEN, K-TEA, and CUTRINE-PLUS have no appreciable vapor pressure, there is no hazard from inhalation.

# 2,4-D

A. Chemical Name and Formulations:

Chemical name: (2,4-dichlorophenoxy) acetic acid

Formulations:

- AQUA-KLEEN (19% acid equivalent (ae), butoxethyl ester of 2,4-D, granular)
- WEEDAR 64 (38.9% ae, dimethylamine or n-alkylamine salt of 2,4-D, liquid)
- WEED-RHAP A-6D (57.4% ae, dimethylamine or n-alkylamine salt of 2,4-D liquid)
- VISKO-RHAP A-3D (33.92% ae, dimethylamine or n-alkylamine salt of 2,4-D, liquid)
- WEEDTRINE II (18.8% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- WEED-RHAP LV-4D (46.3% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- VEGATROL LV-6D (62.5% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- ESTERON 99 (43.4% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- SEE 2,4D (40.9% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)

B. Mode of Action: Somewhat selective, systemic growth regulator with hormonelike activity; readily translocated throughout plant, especially from foliage to roots; inhibits cell division of new tissue and stimulates cell division of some mature plant tissues, resulting in growth inhibition, necrosis of apical growth, and eventually, total cell disruption and plant death; low concentrations may stimulate growth.

C. Application:

- Liquid formulations:
  - Surface or aerial applications; subsurface application for submersed vegetation.
  - Surface applications with dilute or concentrated product, using conventional spray equipment from boat or shore.
  - Aerial spraying with dilute product; do not exceed 40 psi at the nozzles.
  - Subsurface applications using weighted trailing hoses from boat.
- Granular formulations:
  - Surface or aerial applications using conventional mechanical spreaders or comparable equipment for large areas or a portable spreader for spot treatments.
- Ester formulations are volatile, and care should be exercised when considering their use, particularly in aerial applications.

D. Timing of Application: For best results, apply in spring or early summer when young vegetation is actively growing.

E. Application Rates: Follow herbicide label directions for specific rates.

- Liquid formulation:
  Waterhyacinth and emersed vegetation control:
  2 to 4 kg ae per hectare (2 to 4 lb ae/acre) (2 to 3.8 ℓ of 38.9% ae formulation per hectare) (2 to 4 pints/acre).
- Canal bank vegetation control: 1 to 2 kg ae per hectare (1 to 2 lb ae/acre)
- Watermilfoil control (TVA system): 9.5 to 38 kg ae per hectare (10 to 40 lb ae/acre); 23 to 93 ℓ of WEEDAR 64 per hectare) (2.5 to 10 gal/acre); use concentrate for more dilute formulations (e.g., 38.9% ae) or diluted mixture for more concentrated formulations; use higher rate for areas with heavier infestations.
- Granular formulation:
  Submersed vegetation control: 20 to 40 kg ae per hectare (20 to 40 lb ae/acre); use higher rate for areas with heavier infestations.

F. Maximum Water Concentration: Should not exceed 0.1 mg/ℓ (ppm); delay use of treated water for irrigation for 3 weeks posttreatment unless an approved assay shows water does not contain more than 0.1 mg/ℓ (ppm) 2,4-D acid. Low persistence in water, with half-life less than 2 weeks.

G. Use Restrictions:

- Liquid formulations registered for use solely for floating (e.g., waterhyacinth) and emergent vegetation control; AQUA-KLEEN and WEEDAR 64 allowed for Eurasian watermilfoil control in TVA lake systems only.
- Special Local Needs (Section 24c) and Emergency Exemption (Section 18) lables may exist in some states.
- Do not use treated water for irrigation, agricultural sprays, livestock watering, or domestic water supplies for 3 weeks after application or unless approved assay shows water does not contain more than 0.1 mg/ℓ (ppm) 2,4-D acid. Amine formulations may be tested at concentrations as low as 0.001 mg/ℓ (ppm).
- Do not spray liquid during high wind conditions, to minimize spray drift to nontarget vegetation.
- Can be used in slow-moving water bodies and turbid water.
- Liquid formulations registered for treating canal and ditchbank emergent vegetation in 17 Western States (see label).
- Contact state or local fish and game agency for specific restrictions on fishing, swimming, or domestic use.

H. Waiting Period: Approximately 2 weeks for control of most vegetation; tissue damage evident within 2 to 4 days with liquid and a week with granular formulations. Regrowth evident within 4 to 5 weeks if roots are not killed.

I. Toxicological Data:

| Species | 2,4-D Formulation* (% ae) | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|---|
| Lake trout | 2,4-D acid (100%) | Static | 96 | 35-56 |
| Bluegill sunfish | 2,4-D BEE (65.2%) | Static | 96 | 1.1-1.3 |

* BEE = butoxyethyl ester; DMA = dimethylamine salt; IOE = isooctyl ester.

| Species | 2,4-D Formulation (% ae) | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|---|
| Fathead minnow | 2,4-D BEE (65.2%) | Static | 96 | 2.5-4.2 |
| Rainbow trout | 2,4-D DMA (49%) | Static | 96 | >100 |
| Bluegill sunfish | 2,4-D DMA (49%) | Static | 96 | 123-230 |
| Fathead minnow | 2,4-D DMA (49%) | Static | 96 | 245-458 |
| Amphipod (*Gammarus fasciatus*) | 2,4-D BEE (62.5%) | Static | 96 | 4.5-8.3 |
| Cladoceran (*Daphnia magna*) | 2,4-D BEE (62.5%) | Static | 96 | 4.5-9.1 |
| Amphipod (*G. fasciatus*) | 2,4-D IOE (67%) | Static | 96 | 1.9-3.0 |
| Amphipod (*G. fasciatus*) | 2,4-D DMA (49%) | Static | 96 | >100 |

- Ester formulations of 2,4-D are 50 to 200 times more toxic to fish than amine formulations, but toxic effects are rarely observed under field conditions.
- Ester and amine formulations of 2,4-D appear more toxic at low pH (e.g., 6.5) versus higher pH.

J. Precautions:

- To prevent low dissolved oxygen, do not retreat water until killed vegetation decomposes, about 4 to 5 weeks after initial application. Do not treat entire water body at one time; treat in strips separated by buffer zones.
- Avoid spray drift outside treatment area; do not conduct aerial spraying if wind speed is above 8 km per hour (5 mph); use drift control agents.
- Do not treat areas of water lacking aquatic vegetation.
- Follow directions carefully if using oil-soluble amine formulations, requiring a two-fluid spray system.
- Avoid application of liquid formulations during high wind or flow conditions.

K. Field Instructions:

- Use spray drift-control agents (e.g., thickeners, invert emulsions) with liquid formulations; use coarse sprays.
- Apply liquid and granular formulations in strips separated by buffer zones.
- Delay follow-up treatment for 4 to 5 weeks after initial application to allow for vegetation decomposition.
- Use higher treatment rate for heavily infested areas or if water is unusually high in pH and alkalinity.
- Use proper equipment and recommended mixtures when applying oil-soluble amine formulations.
- Do not enter treated area without protective clothing until spray has dried.

L. Adjuvant Use:

- Polymeric thickeners or invert emulsions are recommended with liquid formulations, especially when sprayed on floating or emersed vegetation.
- Oil-soluble amine formulations (e.g., VISKO-RHAP A-3D) require pre-mixing with kerosene or related oil-soluble solvent; use required mixing equipment.

M. Application Techniques:

- When applying by boat, divide formulation so as to provide material for application in a crisscross pattern; apply back and forth, with sharp turns, followed by an equivalent application at right angles to the first set.
- Recommend placing markers at corners of treatment area to use as directional guides and to avoid excessive overlap of treatments.
- Recommend use of 15- to 30-m (50- to 100-ft) treatment lanes separated by equivalent-sized buffer zones; treatment immediately adjacent to shore is not recommended or needed.

N. Antidote Information:

- Internal: If swallowed, induce vomiting by touching back of throat or give strong salt water to drink; repeat until vomit is clear. Call a physician immediately and the following emergency number, collect (24 hr a day): (304) 744-3487 (Rhône-Poulenc).
- External: Wash skin with soap and water. Flush eyes with water for at least 15 minutes and get medical attention.

# Dicamba

A. Chemical Name and Formulation:
Chemical name: 3,6-dichloro-o-anisic acid
Formulation: BANVEL 720 (10.6% dicamba + 20.4% 2,4-D, dicamba dimethylamine, liquid)

B. Mode of Action: Selective herbicide absorbed and translocated from both leaves and roots with major accumulation in apical meristems and other areas with high metabolic activity; growth hormonelike properties; causes epinasty, defoliation, swelling of stems, and destruction of conductive tissues, death of growing points, loss of apical dominance, and ultimately, necrosis.

C. Application: Water-soluble liquid is applied as a surface spray from shoreline, boat, or helicopter; mixed with water, plus emulsifiers, surfactants, or drift control agents. Completely wet emergent foliage to runoff with dilute spray mix.

D. Timing of Application: Do not apply prior to emergence of vegetation above or to surface of water. Plants are most sensitive during their active growing stage.

D. Application Rates:
- Ground or boat application: use 2 to 6 kg active ingredient (ai) (2 to 6 qt liquid/surface acre) in 50 to 100 gal spray mix, as directed on label. Aerial application: use 1.5 to 5 kg ai per hectare (1.5 to 5 qt liquid/surface acre) in 8 to 20 gal spray mix, as directed on label.
- Cattail treatment requires 4 to 6 kg ai per hectare (4 to 6 lb/surface acre) plus 6 kg dalapon 85% per hectare (6 lb dalapon 85% per surface acre).

F. Maximum Water Concentration: Not specified; not for direct application to water bodies. Half-life is 2 to 6 weeks in most water bodies.

G. Use Restrictions:
- Treated water should not be used for irrigation purposes within 14 days of application.
- Do not graze dairy animals on treated area for 7 days after treatment.
- Direct application to water is not permitted.
- Do not contaminate water used for domestic purposes.
- Registration for aquatic use is presently limited to 10 States (Alabama, Florida, Georgia, Indiana, Louisiana, Mississippi, South Carolina, Tennessee, Texas, and Virginia).

H. Waiting Period: None specified.

I. Toxicological Data:*

| Species | Condition | Exposure Period hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 12° C (54° F) | 96 | 28 |
| Bluegill sunfish | Static, 12° C | 96 | >50 |
| Amphipod (*Gammarus fasciatus*) | Static, 15° C (59° F) | 96 | >100 |
| Cladoceran (*Daphnia magna*) | Static, 21° C (70° F) | 48 | >100** |

* Data are for 88% technical dicamba; the dimethylamine salt formulations may show slightly greater toxicity.
** EC-50 was evaluated.

- Herbicide formulation shows low order of toxicity to fish, other aquatic organisms, and wildlife.

J. Precautions:
- Harmful if swallowed; shows extreme irritation to eyes and mild irritation to skin; not readily absorbed through skin.
- Avoid excess spraying of soil as herbicide is readily leached from soil.
- Do not use aerial application if sensitive crops or nontarget plants are growing in immediate vicinity.
- Do not apply during periods of gusty wind or if wind exceeds 24 km per hour (15 mph).
- Do not spray submersed vegetation in water, only emergent growth.

K. Field Instructions:
- Avoid heavy application to soil or excessive runoff from vegetation; wet vegetation thoroughly, however.
- Avoid spray drift; use drift-reducing additives.
- Do not use aerial equipment in areas adjacent to sensitive crops or desirable vegetation.
- Follow label instructions for proper cleaning of equipment.

L. Adjuvant Use: Recommend use of oil-water emulsions, including invert systems, or other spray drift-reducing agent.

M. Application Techniques:
- Use coarse-spray nozzles and spray drift retardants (foams or invert system) to avoid drift to nontarget vegetation.
- Avoid spraying across areas of water lacking emergent vegetation.
- Avoid application during high or gusty wind conditions.
- Prior to large-scale mixing, perform a compatibility test, using all spray mix components in small quantities; if herbicide does not form a gel, precipitate, or stratification, the spray mix is compatible.

N. Antidote Information:

- Internal: If swallowed, drink 1 to 2 glasses of water and induce vomiting by sticking finger down back of throat (or other means). Do not induce vomiting if victim is unconscious. Call a physician.
- External: Flush eyes with plenty of water for at least 15 minutes and get medical attention. Wash exposed skin thoroughly with soap and water; wash contaminated clothing before reuse.

# Dichlobenil

A. Chemical Name and Formulations:
Chemical name: 2,6-dichlorobenzonitrile
Formulations:

| | |
|---|---|
| • CASORON 10G | (10% ai, dichlobenil, granular) |
| • NOROSAC 10G | (10% ai, dichlobenil, granular) |
| • CASORON G-SR | (20% ai, dichlobenil, slow-release, granular) |
| • CASORON G Forte | (20% ai, granular) |

B. Mode of Action: Nonselective herbicide that is absorbed mainly by roots but also by submersed leaves and stems upon being released from granules in water column; causes disruption of plant cell division, resulting in plant deterioration. Major route of action seems to be through the soil to the roots.

C. Application:

- Granular formulations can be applied from boat or shoreline to water surface.
- Uniform distribution is essential since each granule is active only in its immediate surroundings.
- Applied to nonflowing waters and to dry bottoms and shorelines of ponds, reservoirs, and lakes.
- Dichlobenil can be applied to flowing water at 1.5 times the recommended dosage rate for slow-moving water.

D. Timing of Application: Application immediately before initiation of new growth provides the best results, such as in early spring.

E. Application Rates:
Water surface:

| Water Depth m (ft) | Granules 10G kg/ha (lb/acre) |
|---|---|
| <0.6 (<2) | 111 (100) |
| 0.6-1.5 (2-5) | 139 (125 |
| >1.5 (>5) | 166 (150) |

Exposed bottom: Evenly spread 70 to 100 kg/ha (lb/acre); use the lower rate if the soil is wet at time of application or if the water is <1 ft deep. Ponds or reservoirs with drawdown should be refilled promptly after treatment.

F. Maximum Water Concentration: No values are given, but 3 mg/ℓ (ppm) is recommended. Herbicide tends to be readily absorbed to sediment and rapidly and completely broken down in water within 2 weeks. Effective dose of active ingredient is 2 to 3 mg/ℓ (ppm).

G. Use Restrictions:

- Treated water should not be used for livestock or human consumption or crop irrigation.
- A 90-day waiting period is required prior to use of fish from treated water for food or feed.
- Not recommended for use in commercial fish or shellfish waters.

H. Waiting Period: Existing revegetation is controlled very slowly. Therefore, dichlobenil should be applied in early spring before weed growth begins. This produces a season-long weed control period. Algae are not controlled.

I. Toxicological Data: Recommended dosages provide dichlobenil concentrations well below the danger levels to spawning fish, phytoplankton, and other food chain organisms.

| Species | Condition | Exposure Period hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 13° C (55° F) | 96 | 6.3 |
| Bluegill sunfish | Static, 18° C (64° F) | 96 | 8.3 |
| Crustacea (*Daphnia pulex*) | Static, 1st instar, 15° C (59° F) | 96 | 3.7 |
| Crustacea (*Gammarus lacustris*) | Static, mature, 21° C (70° F) | 96 | 11.0 |

Variations in water hardness have little effect on fish toxicity. Toxicity of the principal metabolite, 2,6-dichlorobenzamide, is much less than dichlobenil.

J. Precautions:

- Dichlobenil is not selective in action and may kill all types of vegetation in contact with the active ingredient.
- Store in tightly closed containers in a dry place.
- Do not treat water needed for crop irrigation within a 4-week period.
- Avoid breathing dust from product.

K. Field Instructions:

- Even application of granules is required for effective control since each granule is active mainly in its immediate surroundings.
- The herbicide is directly absorbed by plants, especially by roots through the sediment.
- Avoid application near desirable vegetation as this herbicide is nonselective.
- If applied to drained surfaces, refill with water as soon as possible to avoid volatilization of active ingredient.
- Dispose of empty bags in a sanitary landfill or by incineration if allowed by state or local authorities.

L. Adjuvant Use: Use of adjuvants is not specified.

M. Application Techniques:

- Good results are obtained by motorized knapsack applicators, used from a boat or shore.
- Long stretches of canals and ditches can be treated with tractor-mounted equipment.
- Application should be made during periods of calm, when wave action or water flow rate is minimal.
- Avoid excessive propeller turbulence if using a motorboat.

N. Antidote Information:

- Internal: Induce vomiting by drinking water and touching back of throat with finger (or other means). Call a physician immediately.
- External: Flush eyes with water for 15 minutes. Wash skin thoroughly with soap and water. If inhaled, remove individual to fresh air.

# Diquat

A. Chemical Name and Formulations:
Chemical name: 6,7-dihydrodipyrido(1,2-α:2',1'-c) pyrazinediium dibromide
Formulations:
- Ortho DIQUAT - H/A (35.3% ai, diquat dibromide)
- WEEDTRINE-D (8.53% ai, diquat dibromide)

B. Mode of Action: Contact type, nonselective, absorbed by foliage but not by buried roots due to rapid inactivation by clay minerals; causes rapid inactivation of cells and cellular functions through release of strong oxidants; only local translocation.

C. Application:
- Water-soluble liquid; surface or aerial spray for floating vegetation; surface or bottom application with trailing hoses for submersed vegetation.
- Herbicide concentrate or up to 20:1 dilution with water is recommended for subsurface injection; aerial sprays should be diluted 15- to 400-fold with water, depending on plant species or growth stage (see label).
- Efficacy is greatly reduced in muddy water or with mud-coated vegetation.
- Can be used in quiescent or flowing water (Ortho DIQUAT only).
- Mixture with complexed copper formulations often provides improved efficacy.

D. Timing of Application: Throughout the entire growing season; recommend control of early growth. One application per growing season anticipated.

E. Application Rates:
- Submersed vegetation: 9.4 to 18.7 ℓ/ha (8 to 16 pt/surface acre) (add 3.4 to 5.6 kg/ha (3 to 5 lb/acre) copper ion complex for hydrilla, coontail, and bladderwort).
- Floating vegetation: 4.7 to 7.0 ℓ/ha (4 to 6 pt/surface acre) (except duckweed: 9.4 to 18.7 ℓ/ha (8 to 16 pt/surface acre)).
- Marginal emersed vegetation: 9.4 ℓ (8 pt/surface acre).
- Filamentous algae: 3.5 to 9.4 ℓ/ha (3 to 8 pt/surface acre) (average water depth).

F. Maximum Water Concentration: Do not exceed 2 mg/ℓ.

G. Use Restrictions:
- Do not use water for animal or human consumption, swimming, or spraying within 14 days of treatment unless approved analysis shows that water does not contain more than 0.01 mg/ℓ diquat ion.
- Do not use herbicide in muddy water or on vegetation coated with mud.
- Treat only one third to one half of densely vegetated areas at a time and wait 10 to 14 days between treatments.

H. Waiting Period: Plants absorb diquat rapidly; plant decline is usually within less than 7 days posttreatment.

I. Toxicological Data:

| Species | Condition | Exposure Period, hr | Acute Toxicity, $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Channel catfish | Static | 96 | 10 |
| Largemouth bass | Static | 96 | 7.8-10 |
| Bluegill sunfish | Static | 96 | 10-140 |
| Rainbow trout | Static | 96 | 5-11.2 |
| Fathead minnow | Static | 96 | 14.0 |
| Cladoceran (*Daphnia pulex*) | Static | 192 | 1.0 |
| Midge larvae | Static | 96 | >100 |

J. Precautions:
- Avoid spray drift to food, forage, or desirable vegetation; do not store or transport near feed or food.
- Do not get diquat on skin, eyes, or clothing; may be fatal if ingested, inhaled, or absorbed through skin; symptoms of injury may be delayed; strong skin irritant.
- Use facemask, gloves, and waterproof clothing and footwear while spraying or when reentering treated areas.

K. Field Instructions:
- Recommend use of nonionic surfactant (e.g., Ortho X-77 spreader) or thickener (e.g., Nalquatic) when spraying floating or emersed vegetation.
- Do not treat muddy water or vegetation coated with mud; use clean water for making herbicide dilutions.
- Avoid creating muddy water during application.
- Do not apply under conditions of high wind or wave action.
- Treat heavy plant infestations in sections; subsequent treatment should be after a 10-day waiting period to avoid low dissolved oxygen levels.
- Subsurface injections should be done in strips, 12.2 m (40 ft) apart with early growth and not more than 6.1 (20 ft) apart in thick mature growth.
- Treat with complexed copper.

L. Adjuvant Use:
- For aerial application, use nonionic surfactant (e.g., Ortho X-77 Spreader) at rate of 0.47 ℓ (1 pt) surfactant per 568 to 757 ℓ (150 to 200 gal) spray mixture.
- Use of a polymeric thickener (e.g., Nalquatic) is recommended for submersed growth at rate of 3.79 ℓ (8 pt) per 379 to 568 ℓ (100 to 150 gal) mixture.
- Complexed copper ion in combination with diquat is recommended for improved efficacy for some macrophytes (hydrilla, coontail, bladderwort) and algae control.

M. Application Techniques:

Use water carrier, thickener, or invert emulsion carrier for best results.

- Submersed vegetation:

  Boat with weighted trailing hoses, apply dilute concentrate 7.6 to 15 cm (3 to 6 in.) below water surface or (for firm sediments) 31 to 61 cm (1 to 2 ft) off bottom.

  Boat with sprayer, use concentrate poured directly from original containers; apply in strips with widths of 6.1 m (20 ft) (new growth) to 12.2 m (40 ft) (topped-out mature growth).

- Floating or emergent vegetation:

  Use conventional spray equipment from boat, shore, or helicopter, using techniques for minimizing spray drift.

  Use nonionic surfactant with dilute tank mix.

N. Antidote Information:

- Internal: If conscious, give large amount of water to drink and force vomiting by placing finger at back of throat (or by other method). Call a physician immediately and the following emergency numbers: (800) 845-7633 (South Carolina: (800) 922-0193) for National Agricultural Chemical Association Medical Hotline or (415) 233-3737 for Valent USA Corporation (formerly Chevron Chemical Company) emergency information.
- External: Flush eyes and skin immediately with water for at least 15 minutes. For eyes, get medical attention. Remove and wash contaminated clothing before reuse and daily during treatment period.

# Endothall

A. Chemical Name and Formulations:
Chemical name: 7-oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid
Formulations:

- AQUATHOL K (40.3% ai, dipotassium salt of endothall, liquid)
- AQUATHOL Granular (10.1% ai, dipotassium salt of endothall, granular)
- HYDROTHOL 191 (53.0% ai, mono(N,N-dimethylalkylamine) salt of endothall, liquid)
- HYDROTHOL 191 (11.2% ai, mono(N,N-dimethylalkylamine) salt of endothall, granular)

B. Mode of Action: Contact type, membrane-active herbicide that inhibits protein synthesis upon plant metabolism; limited translocation throughout plant tissues.

C. Application:
Liquid suspension: total water column treatment, bottom water treatment treatment, invert and polymer additions.
Granules: surface application of water body.
General information:

- Formulations can be used in quiescent and flowing water (irrigation and drainage canals); canal treatment not allowed in California.
- Dimethylalkylamine salt of endothall (granular form) for use in rice paddies in California only.

D. Timing of Application: Apply soon after emergence of new vegetative growth. Water temperature should be at least 65° F (18° C) prior to application.

E. Application Rates:

- Dipotassium salt of endothall:
  Quiescent water -
  (Average depth): 72 to 119 ℓ/ha (62-102 pt/acre) liquid; 374 to 631 ℓ/ha (320-540 lb/acre) granules.
  Irrigation and drainage canals - Not for use in canals in California.
  Herbicide contact time with target plants should be at least 2 hr.
  Recommended water concentrations for target plants are given in the tabulation that follows.

| Plant | Entire Pond or Large Area Treatment, mg/ℓ | Sectional or Lake Margin Treatment, mg/ℓ |
|---|---|---|
| Hydrilla | 2-3 | 3-4 |
| Watermilfoil | 2-3 | 3-4 |
| Waterstargrass | 2-3 | 3-4 |
| Pondweeds | 1-3 | 2-4 |
| Coontail | 1-2 | 2-3 |
| Horned pondweed | 1-2 | 2-3 |
| Naiads | 0.5-1.5 | 2-3 |

- Mono(N,N-dimethylalkylamine) salt of endothall:
  - Quiescent water -
    - Formulation recommended only for sectional or marginal treatment of water bodies stocked with fish, due to relatively high fish toxicity.
  - Irrigation and drainage canals -
    - Herbicide contact time with target plants should be at least 2 hr.
- Recommended water concentrations for target plants:
  - Quiescent water - 0.5 to 2.5 mg/ℓ. Use dosages over 1 mg/ℓ only on very narrow margins or in areas where some fish kill is not objectionable. Do not treat more than 10 percent of water body at one time with more than 1 mg/ℓ.
  - Canals -
    - Heavy infestations: 3-5 mg/ℓ.
    - Moderate to light infestations: 1-2 mg/ℓ.

F. Maximum Water Concentration:

Dipotassium salt of endothall: Do not exceed 5 mg/ℓ, although low toxicity to fish is indicated.

Mono(N,N-dimethylalkylamine) salt of endothall: Do not exceed 2.5 mg/ℓ; only small sectional or marginal areas of water bodies containing fish should exceed water concentrations greater than 1 mg/ℓ.

G. Use Restrictions:

| Usage | Dipotassium Endothall | Dimethylalkylamine Endothall |
|---|---|---|
| Swimming | 24 hr | 24 hr |
| Drinking water (humans and livestock) | 7-14 days | ≤0.3 mg/ℓ, 7 days<br>0.3-3.0 mg/ℓ, 14 days<br>3.0-5.0 mg/ℓ, 25 days |
| Fish consumption (from treated water) | 3 days | 3 days |
| Irrigation of nonfood crops | 7 days | 7 days |
| Release of water from rice fields (California only) | Not applicable | 10 days (granular only) |
| In muddy water water | Yes | Yes |
| In slow-flowing water | Yes | Yes |

H. Waiting Period: Target plants show initial signs of tissue damage (necrosis) within 1 to 3 days; control of vegetation is usually obtained in 7 to 14 days.

I. Toxicological Data:
Dipotassium endothall:

| Species | Conditions | Exposure Period | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Largemouth bass | Static | 48 hr | 200-320 |
| Largemouth bass | Flowthrough | 96 hr | >135 |
| Largemouth bass | Repeat exposure | 7 days | 95-115* |
| Chinook salmon | Static | 96 hr | 82 |
| Chinook salmon | Repeat exposure | 14 days | 62.5 |
| Bluegill sunfish | Static | 96 hr | 125 |
| Bluegill sunfish | Repeat exposure | 21 days | 100* |
| Rainbow trout | Repeat exposure | 21 days | 10* |
| Crustacea (*Gammarus lacustris*) | Static | 96 hr | >320 |
| Midge larvae | Static | 72 hr | 120 |

* Concentration producing minimal or no mortality.

Dimethylalkylamine endothall:

| Species | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Largemouth bass | Static | 96 | 0.1-0.3* |
| Bluegill sunfish | Static | 48 | 0.8 |
| Bluegill sunfish | Static | 96 | 0.06-0.2* |
| Redear sunfish | Static | 96 | 0.1-0.2* |
| Golden shiner | Flowthrough | 120 | 0.32-1.6 |

* Diamine salt.

- Dimethylalkylamine salt of endothall is more toxic than the dipotassium salt to fish and other nontarget organisms.
- Increasing water temperature causes a slight increase in toxicity of this formulation.
- Rapid microbial decomposition of endothall precludes its bioaccumulation.
- No hazardous metabolites have been noted to form.

J. Precautions:

- Do not use fish from treated water for food or feed within 3 days of treatment.
- Do not use water for domestic purposes until 7 to 14 days after treatment (see Use Restrictions).
- Fish will be killed by dosages of dimethylalkylamine endothall in excess of 0.3 mg/ℓ.
- Do not use dimethylalkylamine formulation in marine or estuarine environments due to high toxicity to estuarine organisms.
- Avoid breathing spray mist. Potentially harmful skin absorption is possible if bathing and change of clothing are not initiated daily during use.
- Causes severe eye and skin irritation; wear goggles and rubber gloves while handling concentrate. Harmful or fatal if swallowed.

K. Field Instructions:

- Necessary approval and/or permits should be obtained.
- Small infested areas best treated with granular products.
- Adjuvant polymers aid in application of liquid products and may allow lower application rates.
- Dimethylalkylamine formulation should be applied by professional applicator.
- Most algae can be effectively treated with dimethylalkylamine endothall or dipotassium endothall in combination with complexed copper.
- Treat water containing heavy vegetation in sections to prevent low dissolved oxygen levels caused by vegetation decay.

- Treat surface vegetation with undiluted liquid formulations.
- Apply liquid herbicide when wind and water flow rate are minimal to prevent rapid dispersal from treatment area.

L. Adjuvant Use: Polymeric adjuvants (e.g., Nalquatic) with dipotassium salt formulations and Nalcotrol II for mono(N,N-dimethylalkylamine) salt formulations or invert emulsions for liquid formulations.

M. Application Techniques:

- Liquid formulations:

  Aerial, surface application by boat or from shore, and bottom placement of liquids by boat with trailing hoses.

  Recommend use with adjuvants, especially for surface water application.

  Low-dilution applications are recommended for partly emersed plants.

  Bottom placement is recommended for bottom growth.

  Metering devices are recommended for applications to flowing water (ditches and canals).
- Granular formulations:

  Aerial and surface application from boat or shore, by blowers or mechanical spreaders.

N. Antidote Information:

- Internal: Promptly drink large quantities of milk, egg whites, or gelatin solution, or if these are not available, large quantities of water. Avoid alcohol. Measures against circulatory shock, respiratory depression, and convulsion may be needed. Call a physician immediately and the following emergency numbers: (800) 845-7633 (South Carolina: (800) 922-0193) for National Agricultural Chemical Association Medical Hotline or (206) 627-9101, ext. 250, for Pennwalt Corporation emergency information.
- External: Flush eyes or skin for at least 15 minutes with plenty of water. For eyes, call a physician. Remove and wash contaminated clothing before reuse. Bathe and wash clothing daily during treatment period.

# Fluridone

A. Chemical Name and Formulations:
Chemical name: 1-methyl-3-phenyl-5-[-3(trifluoromethyl)phenyl] -4(1H)-pyridinone
Formulations:
- SONAR 4AS (43.2% ai, fluridone, liquid emulsion)
- SONAR 5P (5% ai, fluridone, pellet)
- SONAR SRP (5% ai, fluridone, slow-release pellet)

B. Mode of Action: Systemic, from submersed foliage to roots or emersed foliage; also absorbed from sediment. Inhibits carotenoid synthesis and thus affects photosynthesis.

C. Application:
Liquid suspension: to water surface, subsurface, or along bottom of water body.
Pellets: surface application of water body. Use only in quiescent lakes and ponds, with little water movement, to avoid rapid dilution; for control of both submersed and emersed vegetation.
Ponds: treat entire water body.
Lakes and reservoirs: establish plots no less than 10 surface acres. Do not treat areas with a large linear aspect, e.g., boat lanes and shorelines.

D. Timing of Application: During spring or summer when weeds are visible and actively growing.

E. Application Rates:

| Treatment Area | Water Depth, m | Liquid, ℓ/ha | Pellets, kg/ha |
|---|---|---|---|
| Ponds | 0.9 | 1.17-2.34* | 11.2-22.4 |
| | 0.9-1.5 | 2.34-3.5 | 22.4-33.6 |
| Lakes/reservoirs | 1.5 | 0.88-1.75 | 0.56-0.84 |
| | 0.9-1.5 | 1.75-3.5 | 0.84-1.12 |
| | 1.5-3.1 | 3.5-4.7 | 1.12-1.68 |
| | 3.1 | 1.75-3.5 | 16.8-33.6 |
| | 1.8-3.7 | 3.5-7.0 | 33.6-67.2 |
| | 3.7 | 4.7-9.4 | 44.8-89.6 |

* The higher rate should be used with dense growth or greater water depth through treatment area.

F. Maximum Water Concentration: Not specified; initial water concentration of approximately 0.1 mg/ℓ is recommended.

G. Use Restrictions: Do not apply within 0.25 mile (0.4 km) of any potable water intake. See "Irrigation Precautions" on label.

H. Waiting Period: Visible herbicidal effects should be noticed on target plants within 7 to 10 days after application, by the appearance of pink or chlorotic growing points. Sixty to 90 days may be required to determine the effectiveness of the herbicide on the target vegetation.

I. Toxicological Data:

| Species | Conditions | Exposure Time | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static | 96 hr | 7.6-11.7 |
| Bluegill sunfish | Static | 96 hr | 9.0-12.5 |
| Channel catfish | Static | 96 hr | 22 |
| Cladoceran (*Daphnia magna*) | Static | 48 hr | 4.4-6.3 |
| Catfish eggs/larvae | Repeat exposure | Chronic | >0.5 |
| Fathead minnow | Repeat exposure | Chronic | >0.5 |
| *Daphnia* reproduction | Repeat exposure | Chronic | >0.2 |

- NOTE: Fluridone was not found to cause genetic mutations or cancer in tested lab animals.

J. Precautions: Avoid contact with eyes, skin, or clothing. Harmful if swallowed, inhaled, or absorbed through skin.

K. Field Instructions:
- Avoid application during high-flow conditions (e.g., after heavy rain or high wind conditions).
- Suspended particulates or muddy water should not greatly affect herbicidal action.
- Avoid application near desirable shoreline trees or shrubs having roots extending into water.
- Herbicide is not effective against algae and, thus, an algicide may be required.
- Emptied container should be rinsed three times with rinse water from the spray tank. Dispose of container by burying, offer for recycling or reconditioning, or puncture and dispose in a sanitary landfill.

L. Adjuvant Use: None specified.

M. Application Techniques:
- May be applied with any available (liquid or pellet) application equipment; uniform application is desirable but not necessary.
- Application of spray or pellets may be from shore or boat.
- No information concerning aerial application or spray drift problems.

N. Antidote Information:
- Internal: No specific information; get medical help immediately. Call physician and emergency telephone number (317) 276-3342 (Elanco).
- External: For eyes and skin, flush with plenty of water; get medical attention if irritation persists.

# Glyphosate

A. Chemical Name and Formulation:
Chemical name: N-(phosphonomethyl)glycine
Formulation: RODEO (53.5% ai, isopropylamine salt of glyphosate, liquid)

B. Mode of Action: Not definite. However, investigators have postulated that biosynthesis of phenylalanine is interrupted through repression of chorismatic acid.

C. Application: To aerial foliage, water soluble; do not apply to submersed or mostly submersed vegetation.

D. Timing of Application: When plants are actively growing.

E. Application Rates:
- Alligatorweed: 7.9 ℓ/ha (6 pt/acre) as broadcast spray; 1.25% solution with hand-held equipment.
- Cattail, maidencane, paragrass, spatterdock: 7.0 ℓ/ha (6 pt/acre) as broadcast spray; 0.75% solution with hand-held equipment.
- Giant cutgrass, waterhyacinth: 7.0 ℓ/ha (6 pt/acre) as broadcast spray; 1% solution with hand-held equipment.
- Torpedograss: 7.0 to 8.8 ℓ/ha (6 to 7.5 pt/acre) as broadcast spray; 0.75 to 1.5% solution with hand-held equipment.
- Other listed perennials: 5.3 to 8.8 ℓ/ha (4.5 to 7.5 pt/acre) as broadcast spray; 0.75 to 1.5% solution with hand-held equipment.

F. Maximum Water Concentration: None is specified; approved for use at all aquatic sites. Recommended concentration is 0.2 mg/ℓ.

G. Use Restrictions:
- No restriction on use of treated water for irrigation, recreation, or domestic purposes.
- Do not apply within 0.8 km (0.5 mile) upstream of potable water intakes.
- Do not exceed 8.8 ℓ/ha (7.5 pt/acre) for each treatment.
- Do not retreat within 24 hr.

H. Waiting Period: Visible effects on most annual plants occur within 2 to 4 days, but perennial plants may not show effects for 7 days or more. Visible effects are gradual wilting and yellowing of plant, advancing to total browning and deterioration. In fact, effects may not appear for up to 4 weeks depending on physiological state of the plants.

I. Toxicological Data:

| Species | Conditions* | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ** |
|---|---|---|---|
| Rainbow trout | Static | 96 | 7.0-11.0 |
| Bluegill sunfish | Static | 96 | 4.2-14.0 |
| Channel catfish | Static | 96 | 11.0-16.0 |
| Cladoceran (*Daphnia magna*) | Static | 48 | 5.3 |

* Toxicity increased with increasing temperature and alkalinity.
** 41% liquid (ROUNDUP).

J. Precautions:

- Do not mix or store this product in galvanized or unlined steel (except stainless steel) due to production of combustible gas (hydrogen).
- Avoid contact with eyes, skin, or clothing.
- Avoid spray drift.

K. Field Instructions:

- Long-term exposure causes corrosion of most exposed metal equipment, unless thoroughly washed after use.
- Rainfall or washing of plants within 6 hr of application can reduce herbicide effectiveness.
- Use of an approved nonionic surfactant is required with this herbicide.
- This product does not provide residual weed control.
- Do not use muddy water for diluting spray solutions due to herbicide inactivation following particulate sorption.

L. Adjuvant Use: Surfactant use is required. Use 0.25 to 0.5% surfactant by total spray volume (950 to 1,892 ml/379 ℓ (1 to 2 qt/100 gal) spray solution). Trademark surfactants: Agri-Dex, CIDE-KICK, Induce, Liqua-wet, Ortho X-77, Passage, R-11, Spreader Sticker, Super Spread 200, and Widespread.

M. Application Techniques: Aerial (except in California), high volume, or hand-held equipment. Drift control additives may be used. Spray to wet foliage without runoff. Use the least amount of water, as possible, to provide adequate foliar wetting.

N. Antidote Information:

- Internal: Call physician and emergency number: (314) 694-4000 (Monsanto).
- External: Eyes should be flushed with plenty of water for at least 15 minutes; skin should be flushed with water; and clothing should be washed before reuse.

# Simazine

A. Chemical Name and Formulation:
Chemical name: 2-chloro-4,6-bis(ethylamino)-s-triazine
Formulation: AQUAZINE (80% ai, simazine, wettable powder)

B. Mode of Action:
- Relatively selective, systemic herbicide with species-specific translocation properties.
- Primary action is by blockage of photosynthesis (electron transport pathways), but rapid action implies other phytotoxic effects, including increased photooxidation through pigment destruction reactions.
- Uptake results in rapid foliar chlorosis followed by necrosis and destruction of all cellular tissues and organelles.
- Low concentrations cause leaf greening and stimulate growth.

C. Application: Using water as the carrier, apply wettable powder as paste or slurry to surface of water at several points from shoreline, or spray dilute slurry suspension over surface of pond. Conventional spray equipment can be used.

D. Timing of Application: Early spring applications are best, i.e., after emergence and before heavy plant growth occurs. Application before water temperature exceeds 24° C (75° F) allows for slower vegetation decay and decreased oxygen stress on aquatic organisms.

E. Application Rates:
- Submersed and floating vegetation:
  1.16 to 2.33 kg/ha (3.4 to 6.8 lb/acre-ft)
  [(0.92 to 1.85 kg ai/ha) (2.7 to 5.4 lb ai/acre-ft)],
  giving concentration of 1 to 2 ppm. For watermeal control, split application and apply half 3 to 4 weeks after first treatment. Use higher rate for heavy infestations. For fanwort, use:
  2.91 kg/hm (8.5 lb/acre ft) [(2.33 kg ai/ha) (6.8 lb ai/acre-ft)].
- Sensitive algae are usually controlled at doses half those for aquatic macrophytes.

F. Maximum Water Concentration: None specified; should not exceed maximum recommended application of 2.5 mg ai/ℓ.

G. Use Restrictions:
- Water from treated ponds may not be used for irrigation, spraying of nontarget vegetation, watering of domestic animals, or for human consumption until 12 months following treatment.
- Fish from treated ponds may be used for human consumption.
- Treated ponds may be used immediately for swimming.

H. Waiting Period:
- Control of submersed plants, except coontail, occurs in 4 to 6 weeks; coontail, in 10 weeks.
- Control of duckweeds occurs in 1 to 5 weeks; watermeal, in 5 to 9 weeks.
- Most algae are controlled within 1 week; bluegreen algae are most rapidly controlled.

I. Toxicological Data: (Technical material, 98.1%, except as stated.)

| Species | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 12° C | 96 | >100 |
| Fathead minnow | Static, 25° C | 96 | 6.4 - >100 |
| Bluegill sunfish | Static | 96 | 16.0 |
| Bluegill sunfish | Static, 24° C | 96 | 90 - 110* |
| Amphipod (*Gammarus fasciatus*) | Static, 15° C | 96 | >100 |
| Cladoceran (*Daphnia magna*) | Static, 21° C | 48 | 0.56 - 2.2** |

* Wettable powder, 80%.
** $EC_{50}$ values.

J. Precautions:

- Do not treat ponds with bordering trees having roots that extend into water; do not spray or spill herbicide on desirable vegetation.
- Avoid contact with skin, eyes, or clothing; wear gloves and long-sleeved shirts and pants. Wash thoroughly after handling and before eating. Use dust aspirator and goggles if inhalation and eye contact with powder is likely.
- Clean equipment with water and discard into treated water; do not use water for irrigation or domestic use within a 12-month period.
- Avoid storage of herbicide at high temperature or in moist areas; normal shelf life is more than 5 years.

K. Field Instructions:

- Approved for farm and recreational ponds, including those containing edible fish.
- Do not use herbicide for spot treatments, due to its slow rate of action.
- Although formulation can be applied as a powder, it is best to use as a slurry or spray by mixing with water over the water surface.

L. Adjuvant Use: None.

M. Application Techniques: Mix convenient quantity of wettable powder (e.g., 2.26 to 4.5 kg (5 to 10 lb)) with water to form thin paste or slurry. Pastes can be applied to several evenly spaced locations along pond shoreline, or uniformly applied as a dilute slurry over pond surface with spray equipment.

N. Antidote Information:

Internal: If large dose is ingested, induce vomiting by placing finger at back of throat; due to its low oral toxicity, special action is not required if insignificant quantities are ingested. Call a physician immediately if a large dose is ingested.

External:

- Flush eyes with plenty of water for at least 15 minutes; get medical attention if irritation persists.
- Wash exposed skin surfaces vigorously with soap and water.
- If inhaled, move to fresh air; give artificial respiration if needed.
- Wash contaminated clothing before reuse.

# SITE FACTORS AFFECTING HERBICIDE SELECTION

The purpose of this section is to examine factors that are specific to a particular site and may affect herbicide selection. The material presented is organized into three parts as outlined below:

a. Water body uses and constraints.

b. Water quality.

c. Hydrology.

Water body uses may greatly affect the choice of a herbicide for a particular situation. For example, the list of candidate herbicides is greatly reduced when a body of water is used as a potable (drinking) water supply. Water quality may influence the effectiveness of certain herbicides. The hydrology of the water body also must be considered in the process of herbicide selection. In many cases, political considerations will influence or limit the list of candidate herbicides. The last section, a review of the fate and persistence of aquatic herbicides, provides a detailed summary of the expected duration of a herbicide in an aquatic system and the partitioning of that herbicide to water, sediments, plants, and animals. This information is very useful because target plant species respond to the concentration of herbicide to which they are exposed, the duration of exposure, and the amount and location of herbicide accumulated in the plant tissues. An aquatic plant manager can use herbicide biodegradation and dilution rates to estimate the duration of exposure. The initial herbicide concentration can then be selected based on the expected persistence.

## Water Body Uses and Constraints

The various demands that are placed on water bodies or resources often influence choices of herbicides for aquatic plant control. It is frequently necessary to consider the uses that are made of an aquatic system during the planning stages of a control program so that appropriate decisions regarding some of the uses can be implemented prior to actual treatment. In some cases, uses can be shifted to alternative water bodies with prior planning.

Whether a herbicide is appropriate for a water body or aquatic system, with a particular water use, is clearly specified on the product label. Most importantly, instructions on the current product label must be followed. For convenience and information, a listing of water uses is provided below.

## Water Use Definitions

Consumptive uses.

a. Municipal water supply. Municipal water supply includes water diverted to water treatment plants for general public distribution. Part of this use may go to industrial users, but so long as a municipal treatment and distribution system is the medium, this is usually considered a municipal water supply.

b. Domestic water supply. Domestic uses are defined as those by individuals for domestic-home use, including ingestion, plumbing, small-scale landscape and gardens, pet-recreational animals (e.g., the family riding horse), and fire control.

c. Industrial water supply. Commercial uses in this category are restricted to partial or complete consumptive use and to those supply media outside the municipal supply system. Examples include power generation evaporation towers, mining dust-control and flushing systems, and chemical manufacturing industries.

d. Irrigation/agriculture. Included in irrigation supply use is all agricultural watering, such as spraying, irrigation, and pesticide (e.g., herbicide) dilution for application. Not included are livestock-related uses as described below.

e. Livestock. Besides ingestion by all livestock (poultry, hogs, goats, sheep, cattle, horses, and other farm or ranch animals), this water use category includes other livestock-related consumptive uses such as washing and cleaning of enclosures, dips and sprays, and cooling-wallowing areas.

Recreation uses.

a. Fishing. Recreational fishing use refers to sport fishing, including public or commercial "pay-for-fishing" barges, as well as water bodies managed for fish spawning and nursery areas necessary for the sport fishery. Not included are commercial fisheries, commercial aquaculture, or hatcheries.

b. Hunting. Included is all sport hunting for water- or wetland-associated game birds and animals. Also included in the recreational hunting category are hunting and trapping solely for domestic use.

c. Swimming. Swimming use includes swimming areas, as well as scuba and skin diving and waterskiing.

## Water Use Restrictions

Herbicides registered for aquatic use in the United States are reviewed and regulated by the US Environmental Protection Agency (USEPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA 1974; 7 U.S.C. 135 et seq., Public Laws 92-516, 94-140, and 95-356) and recent amendments (see Appendix B). The instructions on the label associated with a herbicide are considered a part of compliance with FIFRA and other Federal regulations, and failure to comply with herbicide label restrictions can lead to severe penalties. An important part of herbicide label restrictions is consideration of water use or uses in selection of an appropriate herbicide. This consideration of their use in an aquatic system provides for a balance between the risks involved in use of the herbicide and the benefits that may be realized from its use. Restrictions are listed when there may be unnecessary risk to nontarget species such as people, livestock, or wildlife.

## Herbicide Compatibility

This section identifies those herbicides that are not compatible with specific water body uses. You are cautioned that the labels from which this information was abstracted are constantly changing, and you should review the most current label for the most recent conditions or restrictions. Some of the use restrictions may be only temporary, ranging from 24 hr to a year. If your water body is used for the noted purpose, then due to label restrictions, the herbicide(s) noted cannot be used. The only alternatives are to (a) alter the uses of the water body either temporarily or long term or (b) to apply to the USEPA for a variance or special permission to use the herbicide for your particular problem (see Appendix C for national and regional USEPA office addresses). The latter is an involved process that requires considerable time and economic resources with no assurance that the variance will be granted; however, this may be the only alternative available to you. You will need to resolve these restrictions prior to accepting a herbicide for a desired use. Herbicide tank mixes are regulated based on the most restrictive herbicide in the mixture.

The herbicides listed below are not compatible with the listed water body uses; however, several states have included some of these chemicals under a Special Local Need permit (Sect. 24c, FIFRA, see Appendix D) issued by the USEPA. Verification should be obtained from the appropriate state agency.

a. Municipal/domestic water supply. Dicamba + 2,4-D, dichlobenil, 2,4-D, diquat dibromide, endothall, glyphosate (can be used if greater than 1 mile from water supply intake), and simazine. Currently, only copper may be widely used in municipal water supplies.

b. Industrial water supply. Dicamba + 2,4-D, dichlobenil, glyphosate, and simazine.

c. Irrigation/agriculture. Dicamba + 2,4-D, dichlobenil, diquat dibromide (temporary water use loss), endothall (temporary water use loss), fluridone, and simazine.

d. Livestock. Dichlobenil, diquat dibromide (temporary water use loss), endothall (temporary water use loss), and simazine.

e. Fishing. Dichlobenil and endothall (temporary water use loss).

## Water Quality

Selection of an aquatic herbicide may be strongly influenced by water quality. Chemical and physical characteristics of an aquatic system may not be compatible with some herbicides. The decision to use a herbicide in a particular situation may require some prior information on water quality as well as some routine monitoring immediately prior to treatment and during the treatment period. The following water quality definitions are provided for your information and are water quality parameters that usually affect herbicide selection.

Some water quality restrictions are specifically stated on the label that accompanies each registered aquatic herbicide. Other water quality characteristics may strongly influence the persistence and fate of a herbicide in an aquatic system. The following general guidance on water quality restrictions is abstracted principally from label or manufacturer's information.

### Water Temperature

Some herbicides are ineffective at low temperatures. For others, concentrations must be significantly increased to achieve control of aquatic plants at low water temperatures. At some latitudes in the United States, water temperatures may rarely be in the optimal range for activity of some herbicides. In other cases, you may need to wait for seasonal changes in water temperature to achieve herbicide efficacy. For example, the labels for copper complexes and endothall recommend that water temperatures be greater than 16° to 18° C (60° to 65° F) before applying the herbicide.

### Water pH

The hydrogen ion content, or the water pH, may impact the effectiveness of some aquatic herbicides. For example, the 2,4-D herbicides exhibit increased effectiveness at pH less than 6.0 and decreased effectiveness at pH greater than 8.0. At high pH (>8.0), the highest allowable 2,4-D herbicide concentration may be required to achieve control of the undesirable aquatic plants. You may wish to consider this factor in cost calculations.

## Water Hardness

In some situations, water hardness may restrict selection of an aquatic herbicide. For example, copper-based herbicides must not be used (according to the label) in water containing trout, if the carbonate hardness of the water does not exceed 50 mg/ℓ (as $CaCO_3$). If your aquatic system contains trout and the carbonate hardness is less than 50 mg/ℓ (as $CaCO_3$), you should not consider using copper-containing herbicides because some fish mortality may occur. Trout and other aquatic organisms are more sensitive to copper in soft (low-hardness) water. Labels of copper herbicides carry this recommendation.

## Dissolved Oxygen

For aquatic systems that have important fisheries, dissolved oxygen may be a concern in application of herbicides or other approaches that allow vegetation to decay (consume oxygen) in the aquatic system. The dissolved oxygen content of an aquatic system may vary considerably as a function of time of day, cloud cover, and water temperature. Cooler water contains more dissolved oxygen when all other factors are constant. If dissolved oxygen concentrations approaching 2 mg/ℓ or less are anticipated in your aquatic system, treat small sections over a long period of time (several weeks) or use control methods involving removal of vegetation. This will diminish the risk of oxygen depletion, by reducing the amount of decaying organic material, while allowing fish to move to untreated areas. Below concentrations of 2 mg/ℓ dissolved oxygen, there is some risk of a fish kill that may be an indirect consequence of herbicide application.

## Suspended Solids and Turbidity

According to manufacturer's recommendations and label information, diquat dibromide must not be used in "muddy" water, because the herbicide will be inactivated. Muddy water could be measured as suspended solids in excess of approximately 250 mg/ℓ, and secondarily by turbidity in excess of 50 NTU (nephelometric turbidity units). Subjective estimates can also be used. If you think you have muddy water, delete diquat dibromide from consideration or attempt to get further information or advice.

## Hydrology of Water Body

The hydrology and type of aquatic system must be considered when selecting a herbicide for aquatic plants. Some herbicides are appropriate for certain water bodies and inappropriate for others. For example, lotic (flowing water) systems may require consideration of a different herbicide than lentic (quiescent water) systems. Factors such as flow rate or retention time may prevent sufficient plant/herbicide contact time to achieve the desired level of control. Aquatic herbicide label restrictions may specifically prohibit use of a herbicide in flowing waters. Some aquatic systems may encompass both flowing and static waters. For these systems, the specific water management units (i.e., aquatic environment containing the nuisance plants) must be considered, and appropriate herbicides selected.

# HERBICIDE FATE

Herbicides can control the majority of aquatic and ditchbank vegetation and are the most effective choice in aquatic plant control (Bottrell 1979). However, herbicide effectiveness can be offset by concerns relating to potential risks due to the toxicity or persistence of the herbicide and the incidental or secondary effects it produces (e.g., lowered dissolved oxygen due to macrophyte decomposition). Consequently, the number of chemicals registered by the USEPA for aquatic use is limited and, when they are registered, restrictions are usually imposed (Way and Chancellor 1976) to minimize adverse environmental impact.

Once a herbicide has been applied to an aquatic environment, it becomes distributed among various compartments of that environment, e.g., water, sediment, plants, and other biota. This distribution, when coupled with the persistence or relative residence time of the herbicide in each particular compartment, produces the environmental exposure concentration. It is the exposure concentration of the herbicide in an aquatic environment that produces effects on the target plant species (primary effects), the nontarget plant species, and overall water quality (secondary effects) (Brooker and Edwards 1975). This section examines the aquatic fate and persistence of aquatic herbicides registered in the United States.

Various fate processes are responsible for the eventual removal of a herbicide from aquatic environments. The fate or ultimate residence (where the herbicide and its degradation products will be found) and the time required for the herbicide removal are intimately tied with these processes (Mill et al. 1980; Dickson, Rodgers, and Saleh 1981). The magnitude, and consequently the significance, of each process in overall herbicide degradation and persistence is determined by the rate coefficient, $K$, with a magnitude directly proportional to the importance of the process in the overall herbicide degradation (Mill et al. 1980). Rate coefficient $K$ is expressed in units of time.

Water solubility of a herbicide is one of the most important chemical properties. Environmental fate and persistence of a herbicide are strongly influenced by water solubility and the tendency to partition between the various environmental compartments such as water, sediment, and fish (Mackay 1980). In conjunction with the herbicide water solubility, octanol-water partition coefficients ($K_{ow}$) are very useful in predicting the tendency of the herbicide to concentrate in liquids present in aquatic organisms (Mackay 1980) or the capacity to sorb on sediments. Variable $K_{ow}$ is defined by the equation

$$K_{ow} = \frac{\text{Herbicide concentration in octanol}}{\text{Herbicide concentration in water}}$$

and is inversely proportional to the water solubility of the herbicide (Mackay 1980). Numerous correlations between $K_{ow}$ and bioconcentration factors (BCF) in aquatic organisms have been observed (Chiou et al. 1977, Mackay 1980, Briggs 1981). The larger the $K_{ow}$, the greater the tendency of the herbicide to concentrate in living tissue (bioconcentration).

Bioconcentration is a partitioning process, and the potential of a compound to bioconcentrate within an organism is defined as follows:

$$BCF = \frac{\text{Concentration in living tissue}}{\text{Concentration in water}}$$

The higher the BCF, the greater the potential for bioconcentration and long-term harm to aquatic organisms and aquatic environments (Neely, Branson, and Blau 1974). BCF values may either be determined experimentally, by measuring the concentration of the chemical in water and the organisms, or by employing empirically-derived linear regression equations (Neely, Branson, and Blau 1974; Chiou et al. 1977; Briggs 1981).

Sorption of the herbicide onto the sediment and suspended solids removes the herbicide from aqueous environments (Dickson, Rodgers, and Saleh 1981). Sorption is a dynamic process in which the herbicide is physically and/or chemically bound to and released from sediment particles (Mill et al. 1980). Two types of sorption coefficients are observed in the literature, $K_p$ and $K_{oc}$. The sorption partition coefficient ($K_p$) is defined by the equation

$$K_p = \frac{\text{Concentration in sediment}}{\text{Concentration in water}}$$

The adsorption coefficient, $K_{oc}$, is defined as the $K_p$ normalized or corrected for the organic content of the sediment (Mill et al. 1980) where

$K_{oc}$ = ($K_p$/percent organic carbon) × 100 . Both $K_p$ and $K_{oc}$ can be determined experimentally or derived empirically using linear regression equations developed from observations of sorption in relation to water solubility (Karickhoff, Brown, and Scott 1979) and $K_{ow}$ . The higher the $K_p$ (and $K_{oc}$ ), the greater the role sorption will assume in the removal of the herbicide from water (Dickson, Rodgers, and Saleh 1981). The sorbed herbicide may be released to the water (desorbed) with changing environmental conditions, providing an additional source of the herbicide after system treatment.

A herbicide may move from the water to the atmosphere via volatilization. Volatilization, the gaseous transfer of a compound, is a function of the solubility in water and the vapor pressure of the compound (Mackay 1980, Mill et al. 1980). The tendency for a compound to volatilize is measured by H , the Henry's Law Coefficient, which is calculated by the equation

$$H = \frac{\text{Compound vapor pressure}}{\text{Compound water solubility}}$$

The H is reported for a few herbicides; however, the vapor pressure or a qualitative description (e.g., volatile, not volatile) is reported in many cases. The larger the H , the greater the potential for volatilization, but a direct proportion between volatilization and vapor pressure does not exist due to the solubility factor involved in this transfer process (Mackay 1980). For example, a herbicide with a high vapor pressure and high solubility would tend to volatilize less than a herbicide with a high vapor pressure and relatively low water solubility. Therefore, one should use caution when ranking herbicide volatility on the basis of vapor pressure alone.

Sunlight affects the physical, chemical, and biological components of the aquatic ecosystem. Photolysis, the light-mediated degradation or transformation of a herbicide, is usually represented as a rate coefficient, $K_{ph}$ , or as the percent loss of herbicide per unit time. This degradation can be due to direct sunlight interaction with the herbicide, or indirect, wherein the sunlight sensitizes another compound resulting in herbicide degradation through energy transfer. However, with most herbicides, herbicide photolysis rates are not determined or are insignificant.

Oxidation of a herbicide in an aquatic ecosystem may also occur wherein an oxidant (e.g., $O_2$, -OH, $KMnO_4$) introduces oxygen or oxidizes the herbicide, causing degradation and loss of the phytotoxic properties of the herbicide (Mill et al. 1980). However, herbicide oxidation has rarely been reported.

Very few aquatic herbicides are reported to undergo hydrolysis, wherein water is inserted into sensitive regions of the herbicide structure; this causes the sensitive herbicide molecules to become unstable and fragment. Hydrolysis may occur at acidic, basic, and/or neutral pH values. The specific rates are reported as $K_A$, $K_B$, and $K_N$, respectively (Mill et al. 1980). The overall hydrolysis rate constant, $K_H$, is calculated by the equation

$$K_H = K_A[H^+] + K_N + K_B[OH^-]$$

where $[H^+]$ and $[OH^-]$ are the concentrations of hydrogen and hydroxide ions, respectively (Mill et al. 1980).

Biotransformation and biodegradation are two of the most important fate processes affecting chemicals once they enter aquatic environments (Mill et al. 1980, Scow 1982). Biotransformation occurs when the original compound is changed by microorganisms to a different compound, whereas biodegradation is the microbially mediated change in the parent compound producing carbon dioxide and water (Scow 1982). Although biotransformation may have occurred, the resulting compound may be only slightly less toxic or even more toxic than the parent compound. Biotransformation data are usually presented as a pseudo-first-order rate coefficient, $K_1$ (Mill et al. 1980). Also, biodegradation or ultimate degradation rates are usually not determined.

An overall or total decay rate coefficient, $K_T$, can be calculated for each herbicide by adding the individual first-order fate process decay rate coefficients or $K$ values (Mill et al. 1980). The half-life ($t_{1/2}$), or the time required for the loss of one half of the herbicide concentration, is another method used to represent the overall persistence of a herbicide. This is the method employed in this review to represent each fate process. The $t_{1/2}$ is derived from the equation

$$t_{1/2} = \frac{0.693}{K_T}$$

where the $t_{1/2}$ is given in time units. Herbicides with small $K_T$ values will persist longer in the aquatic environment (large $t_{1/2}$) than herbicides with a larger $K_T$ . Also, the relative importance of each fate process for a particular herbicide may be observed using half-lives.

In many cases, information on specific herbicide properties and rate processes is not or cannot be determined. In these instances, Structure Activity Relationships (SAR) or chemical property estimation methods are employed to obtain estimates. Such methods are commonly used when data gaps in physical, chemical, and biological properties are observed (Lyman, Reehl, and Rosenblatt 1982; Kaiser 1984). The Quantitative Structure Activity Relationships (QSAR) System, developed by Hunter et al. (1984) at Montana State University, was employed in this review for SAR estimations.

This system is a structure activity-based chemical modeling and information system. The QSAR serves as a computer-based interactive chemical data base and environmental fate and effects assessment system designed to provide information concerning the fate and effects of chemicals in various environments. It consists of a series of data bases containing measured property and process values obtained from literature sources and a state-of-the-art QSAR model library. This model is capable of estimating chemical properties, environmental behavior, and toxicity from chemical structure when measured values are not available. Throughout this review, information obtained from QSAR is so indicated.

Each herbicide formulation is discussed below in alphabetical order. Each discussion includes a table that summarizes the structure, fate processes, and concomitant half-lives of the herbicide. Table 1 compares the persistence of herbicides in the aquatic environment.

Table 1

Herbicide Persistence in Aquatic Environments*

| ≤1 Month | 3-12 Months | >12 Months |
|---|---|---|
| Acrolein | Dicamba | Copper |
| 2,4-D | Dichlobenil | |
| Diquat | Fluridone | |
| Endothall | Simazine | |
| Glyphosate | | |

* Adapted from Audus (1976) with several additions.

## Acrolein

Acrolein (2-propenal) is an aquatic herbicide that controls many submersed weeds (Klingman, Aston, and Noordhoff 1975). Acrolein causes eye irritation and tearing and is extremely volatile, flammable, and explosive. Acrolein is primarily used in irrigation canals and drainage ditches (Klingman, Aston, and Noordhoff 1975; Bowmer and Higgins 1976). This herbicide will kill fish and other aquatic wildlife at treatment concentrations (Crafts 1975); therefore, acrolein should be used only in aquatic systems where such resources are not considered important.

Acrolein is soluble in water to 280 g/ℓ at 20° C and has a low octanol water partition coefficient of 0.81 (Callahan et al. 1979) (Table 2). Acrolein is relatively nonpersistent in aquatic environments, with half-lives ranging from less than 1 day (Hiltibran 1962, Callahan et al. 1979) to approximately 2 days (Bowmer and Higgins 1976). The primary fate process, hydration, produces β-hydroxypropionaldehyde, which is then easily biotransformed. A pseudo-first-order rate coefficient for acrolein hydration of 0.032/day, coupled with a biotransformation-decay rate coefficient of $7.8 \times 10^{-3}$/day (<1 percent per day), produces a calculated aqueous half-life of 17.4 days (Bowmer and Higgins 1976, Callahan et al. 1979). However, since acrolein is a volatile herbicide when placed in water (Bowmer and Higgins 1976) and is easily biotransformed, its persistence is greatly reduced in aquatic environments.

Although acrolein is a relatively water-soluble aquatic herbicide with a small $K_{ow}$, fish BCF values ranging from 215 to 344 have been observed for bluegill sunfish (*Lepomis macrochirus*) tissue (USEPA 1980a). Photolysis, hydrolysis, oxidation, and sorption are not considered significant acrolein fate processes (Callahan et al. 1979, Mabey et al. 1981). A sediment adsorption coefficient ($K_{oc}$) of 0.49 from Mabey et al. (1981) is not considered a significant fate process.

## Copper Sulfate and Complexes

Copper sulfate ($CuSO_4$) and complexed coppers have been used for many years in mixtures with endothall and diquat for aquatic macrophyte control (Crafts 1975). However, the copper ion is very persistent in aquatic

Table 2

Structure and Environmental Properties of Acrolein*

| Structure or Property | Value |
|---|---|
| Structure $\quad H_2C=\overset{H}{C}-\overset{H}{C}=O$ | |
| Water solubility (mg/ℓ) | $2.8 \times 10^5$ |
| $K_{ow}$ | 0.81 |
| $K_{oc}$ | 0.49 |
| BCF | 215-344 (kills fish at recommended treatment rates) |
| H (atm $m^3$/mol) | $5.66 \times 10^{-5}$ |
| Photolysis half-life, days | Stable |
| Hydration half-life, days | 21.6 |
| Hydrolysis half-life, days | Stable |
| Biodegradation half-life, days | 88.8 |

* Specific references and ranges are found in the text.

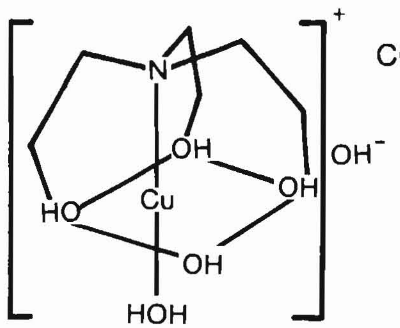
ecosystems and can be recovered from the sediments and remaining vegetation the season after treatment (Audus 1976). Although copper sulfate is primarily used in aquatic environments for algae control, the copper complexes are principally formulated for aquatic plant and algae control.

Ethanolamine, triethanolamine, and ethylenediamine copper complexes are employed in aquatic macrophyte control (Rodgers et al. 1983; Weed Science Society of America (WSSA) 1983) (Table 3). There are no restrictions concerning the use of treated water (assuming the copper concentration is less than 1 mg/ℓ), and the water may even be used for domestic purposes, swimming, fishing, and irrigation immediately after treatment (Crafts 1975). However, once copper has been employed for aquatic macrophyte control, the copper persists indefinitely due to its elemental nature. The majority of the copper applied will eventually sorb to the sediments (WSSA 1983). Wagemann and Barica (1979) observed dissolved copper aqueous half-lives in several Manitoba lakes ranging from 1 to 7 days. For five out of six lakes, the half-lives were 1 to 2 days. Only one lake had an aqueous copper half-life of 7 days. The copper may have sorbed to sediments (Sanchez and Lee 1978) and particulate organic and inorganic complexes (Harrison 1985). Also, copper complexes are the most stable, compared with other transition metal cations (Stumm and Morgan 1970). Up to a pH of 6, dissolved free copper ion $Cu^{2+}$ is the dominant copper species (USEPA 1980b). It is the soluble copper form that is considered phytotoxic and bioavailable with most aquatic organisms (Harrison 1985). Copper complexes and adsorbed species appear to be largely nontoxic (USEPA 1980b). Bioconcentration factors for copper range from 88 for the hard-shelled clam (*Mercenaria mercenaria*) to 2,000 for the green alga *Chlorella vulgaris*. A BCF of 290 was measured for the fathead minnow (*Pimephales promelas*)(USEPA 1980b). During a study of the effect of water hardness and humic acids on copper toxicity to the water flea (*Daphnia magna*), Winner (1985) observed BCF values for copper ranging from 1,200 to 7,100.

The copper Cu Alkanolamine $\cdot$ $3H_2O^{++}$ and Cu Alkanolamine $\cdot$ $2H_2O^{++}$ (CUTRINE-PLUS) complexes, i.e., triethanolamine $[CuN(CH_2CH_2OH)_3 \cdot H_2O]$, (K-LOX), and ethylenediamine $[Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{++}SO_4^{=}]$, are highly water soluble and have very low vapor pressures (<15 mm Hg) (WSSA 1983). The major fate processes affecting the persistence of copper in aquatic systems are sediment sorption and physical export from the system. Both processes would reduce the amount of copper in the aqueous phase. However, sorption does not

Table 3

Structure and Environmental Properties of Copper Ion and Complexes*

| Structure or Property | Value |
|---|---|
| Structure |  COPPER TRIETHANOLAMINE COMPLEX |
| Water solubility (mg/ℓ) | Highly water soluble |
| $K_{ow}$ | Low for complexes |
| $K_{oc}$ | Major process |
| BCF (copper only) | 88-7,100 |
| H (atm $m^3$/mol) | Not applicable |
| Photolysis half-life, days | Not applicable |
| Hydrolysis half-life, days | Not applicable |
| Biodegradation half-life, days | Not applicable |

* Specific references and ranges are found in the text.

remove the copper from the system; the copper has merely been moved from the aqueous phase to the sediment phase and may remain in the system indefinitely.

## 2,4-D

Numerous formulations of 2,4-D [(2,4-dichlorophenoxy)acetic acid)] are registered for aquatic use, but only the two major groups, the esters (butoxyethyl) and the dimethylamine salts, will be discussed since these are the most widely used formulations in aquatic plant control. Plant-growth regulator and selective herbicidal properties of this phenoxy herbicide were not described until 1942-44. Despite the development of many other aquatic herbicides, the phenoxy herbicides, such as 2,4-D, remain major aquatic vegetation management tools (Gangstad 1983). In this review, the formulations will be discussed in the order of acid, butoxyethyl ester, and dimethylamine salt.

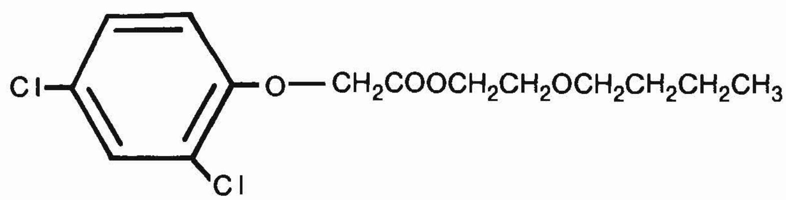
The 2,4-D acid is a white crystalline solid with a water solubility ranging from 600 mg/ℓ (Klingman, Aston, and Noordhoff 1975) to 900 mg/ℓ (WSSA 1983). Although the acid is not generally used in commercial herbicides, it has a $K_{ow}$ ranging from 479 (Hunter et al. 1984) to 645 (Chiou et al. 1977). The $K_{oc}$ values of 330 and 617 were calculated using the regression equations in Neely and Mackay (1982) and Hunter et al. (1984), respectively. However, the affinity of 2,4-D acid for sediments is low. Negligible adsorption has been observed in pure clays and silt (Weber, Perry, and Upchurch 1965; Grover and Smith 1974), and a weak reversible sorption has been shown for organic muck (Harris and Warren 1964). According to Khan (1973, 1974), sorption of 2,4-D to humic material appears to be due to weak physical bonding. A QSAR BCF of 51.2 was calculated (Hunter et al. 1984). Also, an $H$ value of 6.2 $\times 10^{-3}$ atm $m^3$/mol indicates that the acid may volatilize into the atmosphere. The 2,4-D and its derivatives are rapidly degraded through hydrolysis, photolysis, and especially by microbial activity (IRPTC 1984). The data reported by Spain and Van Veld (1983) using the acid form and ecocores (artificial enclosures of riverine sediment and water systems) produced an overall half-life of 14.7 hr for a 2,4-D acid in a preexposed microbial community. Biodegradation half-lives for the acid ranging from 1.4 to 2.8 hr were calculated from the data presented in Ogram et al. (1985). This study was conducted using water and sediment flask systems and bacteria selected for the ability to degrade 2,4-D acid. Biotransformation of 2,4-D in sediments can be rapid during repeated exposure (Torstensson, Stark, and Goransson 1975). McCall, Vrona, and Kelley (1981) reported 2,4-D acid half-lives ranging from 1.5 to 8.5 days on six US soils and the time for 90-percent degradation ranging from 5.9 to 25 days in the same soils.

The butoxyethyl ester (BEE) of 2,4-D is a colorless to amber, oily liquid of low water solubility and low volatility (WSSA 1983). Esters are usually more phytotoxic and also more toxic to fish than amine salts (Klingman, Aston, and Noordhoff 1975; Gangstad 1983). Zepp et al. (1975) report a 2,4-D BEE water solubility of 12 mg/ℓ, whereas a calculated water solubility of 4.7 mg/ℓ was obtained from Hunter et al. (1984) (Table 4). A $K_{ow}$ value of 3,400 was calculated from the regression equation presented in Chiou, Schmedding, and Manes (1982). The $K_{oc}$ values calculated from Chiou, Schmedding, and Manes (1982) and Hunter et al. (1984) were similar. These values, 6,900 and 6,607, were calculated from measured and calculated water solubilities. The Kp values in Fort Cobb Reservoir, Oklahoma, ranged from 43 to 900 (based on 1975 data from the Oklahoma Water Resources Board). These measurements were not taken at equilibrium. A nonequilibrium Kp of 47.1 was calculated, based on data collected during the treatment of Lake Seminole, Georgia, with 2,4-D BEE (Hoeppel and Westerdahl 1983). The majority of sediment samples contained 2,4-D acid levels at or below the High Performance Liquid Chromatography (HPLC) detection level of 0.2 mg/kg. Significant increases in sediment-bound 2,4-D acid were not observed at any time during the 8-month sampling period.

The BCF values in the Fort Cobb Reservoir study ranged from 8,267 to 10,825 for benthic organisms and from 1 to 603 for zooplankton, probably because 2,4-D (BEE) was applied as a granule. Again, concentration equilibrium for 2,4-D BEE was not attained in this study. Also, the 2,4-D BEE concentrations in all fish collected during the Lake Seminole study were below detection limits (0.1 mg/kg) less than 28 days after treatment (Hoeppel and Westerdahl 1983). Whole-body 2,4-D BEE nonequilibrium BCF values for channel catfish (*Ictalurus punctatus*) in aquaria ranged from 2 to 14, and from 6 to 21 for bluegill sunfish (Rodgers and Stalling 1972). These values were related to the concentration or availability of the BEE. The ester was readily hydrolyzed to the acid and then rapidly excreted within these fish. The BCF calculated from Chiou et al. (1977) was 408, whereas 162 was calculated from Veith, DeFoe, and Bergstedt (1979).

Table 4

Structure and Environmental Properties of 2,4-D BEE*

| Structure or Property | Value |
|---|---|
| Structure |  |
| Water solubility (mg/ℓ) | 12 |
| $K_{ow}$ | 3,400 |
| $K_{oc}$ | 6,607-6,900 |
| BCF | 162-408 |
| H (atm $m^3$/mol) | $10^{-5}$-$10^{-7}$ |
| Photolysis half-life, days | 10-20 |
| Hydrolysis half-life, days | 0.02-26 |
| Biodegradation half-life, days | 0.11-2.3 |

* Specific references and ranges are found in the text.

The vapor pressure of 2,4-D BEE at 25° C is $4.5 \times 10^{-6}$ mm Hg (Flint, Alexander, and Funderbuck 1968; Zepp et al. 1975). An H of $2.3 \times 10^{-5}$ atm $m^3$/mol was calculated from QSAR (Hunter et al. 1984), and Thibideaux (1979) reports H values ranging from $10^{-6}$ to $10^{-7}$ atm $m^3$/mol. Volatilization would not be considered a significant fate process for 2,4-D BEE in aquatic systems. The calculated volatilization half-life for 2,4-D BEE at 25° C and 1-m depth in an aquatic system was 895 days (Zepp et al. 1975).

Conflicting reports concerning the photolysis of 2,4-D esters in water have been observed. Aly and Faust (1964) report that sunlight would probably not significantly degrade 2,4-D esters in water. However, Zepp et al. (1975) studied and calculated the photolysis half-life for the BEE of 2,4-D. The half-life ranged from 13 to 20 days, indicating that photolysis may be a significant process affecting 2,4-D BEE persistence in aquatic environments; however, 2,4-D BEE granules are generally several feet below the water surface, where light levels are very low.

The 2,4-D esters are also subject to hydrolysis. A half-life of 3.5 days at a pH of 5.3 in soils for isooctyl and n-butyl 2,4-D esters was calculated from Grover (1973). A 2,4-D BEE hydrolysis half-life of 1.6 days was calculated from the data presented in Rodgers and Stalling (1972) at a pH of 7.0 to 7.2. Aquaria (38-ℓ) filled with 25 ℓ of Missouri well water were employed. Also, a basic hydrolysis half-life of 0.02 day was measured for BEE by Zepp et al. (1975) in laboratory studies. Basic hydrolysis is expected for esters (Morrison and Boyd 1973) and is considered a significant BEE fate process. Neutral hydrolysis was not significant in this study. The acid hydrolysis half-life was 26 days, indicating a lesser fate importance (Zepp et al. 1975). Studies by Aly and Faust (1964) and the USEPA (Zepp et al. 1975) have shown that biological hydrolysis of 2,4-D esters occurs.

In most cases, biological degradation of 2,4-D BEE is considered to be the major fate process in aquatic environments. Paris et al. (1981) observed an average biotransformation half-life in flask studies of 0.11 day. Water samples were obtained from Overlook Lake, Georgia. The overall aqueous 2,4-D BEE half-life in Fort Cobb Reservoir, Oklahoma, was 2.2 days (based on 1975 Oklahoma Water Resources Board data). In a study using 790-ℓ holding tanks containing well water and rainbow trout (*Salmo gairdneri*), overall aqueous half-lives ranged from 0.3 to 0.35 day (Dodson and Mayfield 1979). A 2.3-day half-life for 2,4-D was calculated from Frank and Comes (1967).

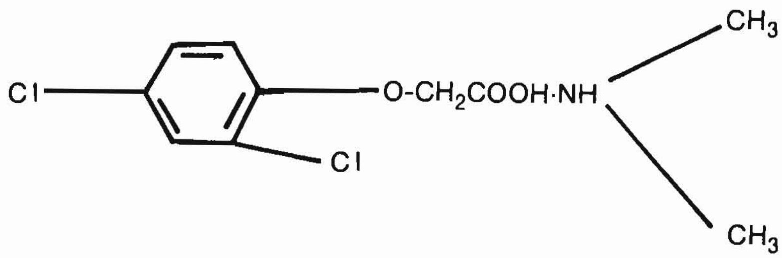
The BEE half-lives in Fort Cobb Reservoir, Oklahoma, were calculated from Otto, Pringle, and Sisneros (1983). The 2,4-D BEE was employed for Eurasian watermilfoil (*Myriophyllum spicatum*) control in various sites throughout the reservoir. Persistence half-lives in water ranged from 1.5 to 1.9 days. Sediment residues (<0.2 mg/kg) persisted longer than 56 days. A granular formulation was employed, which would tend to produce higher residues in sediments than a liquid formulation. However, low sediment residues, ranging from below detection level to 0.316 mg/kg, were observed throughout the study at Fort Cobb, while the water concentrations were usually below 0.1 mg/ℓ (Otto, Pringle, and Sisneros 1983). The maximum sediment residues were observed 1 day after treatment. A half-life for the acid form in the water after 2,4-D BEE treatment of Lake Seminole was calculated as 3.3 days from the data presented in Hoeppel and Westerdahl (1983). The actual 2,4-D BEE concentrations in the water were below detection levels (HPLC) within 7 days after treatment.

Amine salts of 2,4-D, such as dimethylamine (DMA), are the most commonly used form of 2,4-D (Klingman, Aston, and Noordhoff 1975). The DMA salt, the most widely used, is a white crystalline solid with a water solubility of 3,000 g/ℓ (WSSA 1983) (Table 5). High water solubility indicates that the DMA salt of 2,4-D would have extremely low $K_{ow}$, $K_{oc}$, and BCF. The QSAR was unable to estimate these values because the program is not designed for salts (Hunter et al. 1984). Klingman, Aston, and Noordhoff (1975) also stated that this salt has a low vapor pressure. Therefore, a low $H$ would be expected. The $Kp$ values of 0.13 to 0.25, calculated from Schultz and Harman (1973), support the probable low $K_{oc}$ values. This study was conducted in plastic pools containing a clay-loam sediment. No organic carbon levels were stated. Sediment levels of 2,4-D DMA were consistently below the levels of detection in Fort Cobb Reservoir, Oklahoma (Oklahoma Water Resources Board data, 1975), and no $K_{oc}$ could be calculated from the cove treatment.

Nonequilibrium zooplankton BCF values from the same Fort Cobb Reservoir study ranged from 1 to 6.8. Schultz and Harman (1973) observed negligible amounts of 2,4-D DMA in muscle tissue in channel catfish, largemouth bass, and bluegill sunfish (Gangstad 1983). Hoeppel and Westerdahl (1983) also observed 2,4-D concentrations consistently below the detection level for largemouth bass, catfish, sunfish, and bowfin in Lake Seminole.

Table 5

Structure and Environmental Properties of 2,4-D DMA*

| Structure or Property | Value |
|---|---|
| Structure |  |
| Water solubility (mg/ℓ) | $3.0 \times 10^6$ |
| $K_{ow}$ | Low |
| $K_p$ | 0.13-0.25 |
| BCF | 1-7 |
| H (atm $m^3$/mol) | Insignificant |
| Photolysis half-life, days | Insignificant |
| Hydrolysis half-life, days | Insignificant |
| Biodegradation half-life, days | 3.9-11 (based on overall half-life) |

* Specific references and ranges are found in the text.

Hydrolysis and photolysis are not expected to be significant fate processes for the DMA salt of 2,4-D (Frank and Comes 1967). Biotransformation is probably the main fate process affecting 2,4-D DMA persistence in aquatic environments (Averitt and Gangstad 1976). Robson (1968) conducted jar studies with an amine salt of 2,4-D and Lambourne river water (England). An overall half-life of 3.9 days was calculated. This value is considered a good estimate of DMA 2,4-D biotransformation because this process is the major one affecting aquatic persistence. Schultz and Harman (1973) observed aqueous half-lives ranging from 10 to 11 days in plastic pools containing water, hydrosoil, and fish. These half-lives were calculated from data presented in the paper.

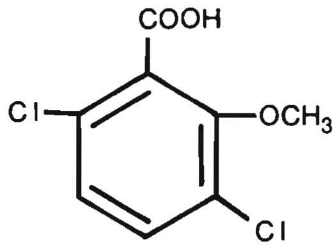
An aqueous half-life of 6.6 days was calculated for 2,4-D DMA in a Fort Cobb Reservoir cove. Half-lives for 2,4-D DMA ranging from 4.2 days in outdoor artificial pools to 2.2 and 3.2 days in Louisiana ponds were calculated from data presented in Averitt and Gangstad (1976). In a review of 2,4-D DMA by Gangstad (1983), aqueous half-lives of 0.5 and 0.8 day were calculated for Okanagan Lake, British Columbia, and 0.8 day for Melton Hill Reservoir in the Tennessee Valley Authority (TVA) system. Aqueous half-lives ranging from 2.5 to 6.2 days were calculated from the data presented in Otto, Pringle, and Sisneros (1983). In this study, several sites in Banks Lake, Washington, were treated with 2,4-D DMA at 22.5 kg/ha. Aqueous concentrations of 2,4-D DMA were below the HPLC detection level within 4 to 7 days after treatment at rates up to 45 kg/ha in Lake Seminole (Hoeppel and Westerdahl 1983).

## Dicamba

Dicamba (3,6-dichloro-*o*-anisic acid) is an aromatic carboxylic acid registered for aquatic use only in Florida as a mixture of the dimethylene salts of dicamba and 2,4-D (Velsicol Chemical Corporation BANVEL 720 label). The environmental fate and persistence of 2,4-D has been discussed in the previous section, and only dicamba fate and persistence will be discussed in this section (Table 6). BANVEL 720, the commercial formulation name, is registered for submersed, floating, and emersed vegetation control and is usually not applied in water where human contact is likely.

Table 6

Structure and Environmental Properties of Dicamba*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | $4.5 \times 10^3$ |
| $K_{ow}$ | 288 |
| $K_{oc}$ | 467 |
| BCF | 0.12-34.6 |
| H (atm $m^3$/mol) | $2.3 \times 10^{-6}$ |
| Photolysis half-life, days | Insignificant |
| Hydrolysis half-life, days | Insignificant |
| Biodegradation half-life, days | 14-433 |

* Specific references and ranges are found in the text.

Dicamba is relatively water soluble and mobile in soils (WSSA 1983). The water solubility of dicamba is 4.5 g/ℓ (WSSA 1983), and a $K_{ow}$ of 288 was calculated from water solubility data (Hunter et al. 1984). These values indicate that dicamba would not sorb significantly to soil and sediment or bioconcentrate; however, based on solubility, a $K_{oc}$ of 467 (Hunter et al. 1984) was calculated. Bioconcentration factors for dicamba range from 0.12 for fish (unidentified) to 9.9 for an unidentified alga (Yu, Hansen, and Booth 1975). A BCF of 34.6 was calculated using the regression equation of Veith, DeFoe, and Bergstedt (1979). Apparently, the $K_{ow}$, $K_{oc}$, and BCF values are overestimated using the equations from various sources. Overestimation of these parameters may be due to the ionic nature (acid) of dicamba, which is not factored into these regression equations.

Dicamba is minimally affected by photolysis in aquatic ecosystems (Kearney and Kaufman 1976) and is stable to both hydrolysis and oxidation (WSSA 1983).

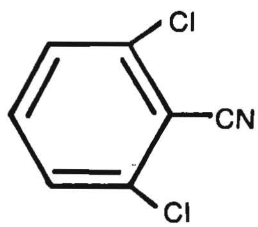
Metabolism by microorganisms appears to be the major degradation pathway under most environmental conditions. Scifres et al. (1973) observed a half-life of 30.1 days for dicamba in two south-central Texas ponds (0.11 and 0.2 ha). In greenhouse studies, sediment appeared to enhance biodegradation, possibly by adding microbial numbers and nutrients. However, a half-life for dicamba in soil was 433 days, calculated from the data presented in the study by Sheets, Smith, and Kaufman (1968). Stewart and Gaul (1977) observed a 95-percent loss of dicamba in 42 days on Canadian dykeland soil. In conclusion, under conditions conducive to high microbial activity, dicamba has a half-life of less than 14 days (WSSA 1983).

## Dichlobenil

Dichlobenil (2,6-dichlorobenzonitrile) is a granular herbicide registered by the USEPA for use only in nonflowing water, such as ponds, lakes, and reservoirs (Table 7). Dichlobenil is soluble in water at 14.6 mg/ℓ (Duphar Chemical Company). The octanol/water partition coefficient is 500, which is higher than that of most aquatic herbicides. Concomitantly, Kp values of 8.6 and 27.9 were calculated from Cope, McCraren, and Eller (1969) and Frank (1972), respectively. Klingman, Aston, and Noordhoff (1975) and Kearney and Kaufman (1976) have also indicated that dichlobenil is expected to sorb

Table 7

Structure and Environmental Properties of Dichlobenil*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | 14.6 |
| $K_{ow}$ | 500 |
| $K_{oc}$ | 912 |
| Kp | 8.6-27.9 |
| BCF | 10-18.5 |
| H (atm $m^3$/mol) | $2.3 \times 10^{-6}$ |
| Photolysis half-life, days | 4-8 |
| Hydrolysis half-life, days (at pH of 5, 7, and 9) | More than 150 days |
| Biodegradation half-life (months) | 1.5-12 |

* Specific references and ranges are found in the text.

readily to sediment. Van Leeuwen and Maas (1985) observed that dichlobenil readily sorbed to humic materials. The QSAR System estimated a $K_{oc}$ of 912 (Hunter et al. 1984). Bioconcentration factors calculated from Cope, McCraren, and Eller (1969) ranged from 9.95 for bass (*Micropterus* sp.) to 18.5 for bluegill. These factors were calculated at the maximum aqueous dichlobenil concentrations. A BCF value of 93.3 was calculated using the equation in Veith, DeFoe, and Bergstedt (1979).

Dichlobenil is stable to photolysis, hydrolysis, and probably oxidation (Kearney and Kaufman 1976). In solution, dichlobenil is photodegraded by 50 percent in 4 to 8 days. A vapor pressure of $5.5 \times 10^{-4}$ mm Hg (20° C) (WSSA 1983), coupled with the water solubility, produced an H value equal to $2.3 \times 10^{-6}$ atm $m^3$/mol. This value indicates that dichlobenil would not have a significant tendency to volatilize from water (Thomas 1982). The QSAR calculated an H of $2.6 \times 10^{-5}$ atm $m^3$/mol (Hunter et al. 1984).

Specific rate coefficients for aqueous biotransformation and biodegradation are not published; however, soil biodegradation values ranged from 0.02/day to 0.002/day (WSSA 1983). These rates correspond to half-lives of 1.2 and 12 months, respectively. A sediment or hydrosoil biotransformation rate of 0.03/day was calculated for a New York pond treated with a granular formulation (Rice, Sikka, and Lynch 1974). Overall rates of dichlobenil loss from water ($K_T$) were calculated from several papers. Rate coefficients of 0.03/day (Cope, McCraren, and Eller 1969; Lay et al. 1984), 0.043/day (Frank 1972), 0.06/day (Ogg 1972), 0.164/day (Cope, McCraren, and Eller 1969), and 0.19/day (Yeo 1967) were calculated. These coefficients correspond to aqueous dichlobenil half-lives ranging from approximately 4 days to 23 days. When granular formulations of dichlobenil are employed, maximum aqueous concentrations are not usually seen until 7 days after treatment (Rice, Sikka, and Lynch 1974).

Dichlobenil has been observed 3 to 12 months after soil treatment (Ashton 1982, WSSA 1983); this persistence is further supported by label warnings which indicate that fish from treated water should not be consumed within 90 days after treatment (Klingman, Aston, and Noordhoff 1975; PBI/Gordon Corporation, NOROSAC 10G label; Uniroyal Chemical, CASORON 10G label). Also, in terrestrial applications, areas treated with dichlobenil should not be reseeded within 24 months of treatment (PBI/Gordon Corporation, Uniroyal Chemical).

# Diquat

Diquat (6,7-dihydrodipyrido[1,2-α:2',1'-c] pyrazinediium ion) (Table 8) is a dipyridylium compound related to quaternary ammonium compounds (Crafts 1975). Diquat controls many submersed aquatic macrophytes and some types of filamentous algae in static and low-turbidity water (Klingman, Aston, and Noordhoff 1975). Diquat is not harmful to most fish at the application rates recommended by the herbicide manufacturers. All of the diquat formulations are liquid bromine salts.

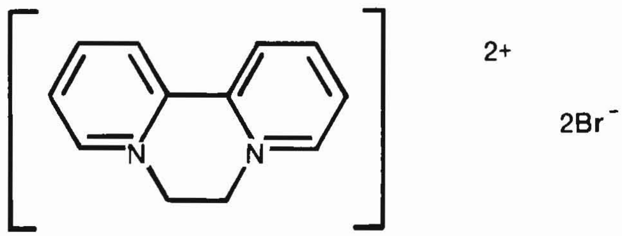
According to QSAR calculations (Hunter et al. 1984), diquat is soluble in water to 568 mg/ℓ with a $K_{ow}$ of 603; however, these calculations do not take into account the cationic nature of diquat. Therefore, the solubility of diquat is expected to be higher (WSSA 1983).

Turbid or "muddy" water substantially reduces the effectiveness of diquat by tightly adsorbing the diquat on the suspended particles (Klingman, Aston, and Noordhoff 1975; Simsiman and Chesters 1976; Simsiman, Daniel, and Chesters 1976). This results from reaction between the double positively charged diquat cation and clay minerals present in sediments to form complexes with the negatively charged sites on the clay minerals. Diquat may even insert into the layer planes of expandable clay minerals, e.g., montmorillonite. Approximately 80 to 95 percent of the diquat added to a water-sediment flask system was sorbed to the sediment within 2 days (Simsiman and Chesters 1976). There are other forms of binding of diquat in soils and sediments (e.g., by incorporation into humus and by normal Langmuir-type (physical) adsorption onto organic matter and particles). In the case of the rather weak Langmuir-type binding, there is a true equilibrium between the quantity adsorbed and free diquat in an aqueous phase in contact with the soil (WSSA 1983). When bound, diquat is not considered bioavailable (Simsiman, Daniel, and Chesters 1976).

Previously defined Kp values, calculated from the data presented in Weber, Perry, and Upchurch (1965), ranged from 708 to 2,863 for montmorillonite clay and from 21 to 57 for kaolinite clay. The Kp values ranged from 17 to 38 in water sediment flasks containing Lake Mendota water and sediments. The $K_{oc}$ or adsorption coefficients for these values, based on an 8.4-percent organic carbon, ranged from 205 to 457 (Simsiman and Chesters 1976). A

Table 8

Structure and Environmental Properties of Diquat*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | 568 |
| $K_{ow}$ | 603 |
| $K_{oc}$ | 205-691 |
| BCF | <1-62 |
| H (atm $m^3$/mol) | Insignificant |
| Photolysis half-life, days | 2-11 |
| Hydrolysis half-life, days | Insignificant |
| Biodegradation half-life, days | 32 |

* Specific references and ranges are found in the text.

QSAR-calculated $K_{oc}$ value of 691 compares favorably with these values (Hunter et al. 1984).

Diquat BCF values are low. Fish from experimental pools treated with 1 mg/ℓ diquat contained concentrations ranging from below the minimum detectable level to a trace (<1.0 mg/kg) (Funderburk and Bozarth 1967). A 4-day BCF for macrophytes of 50 was observed by Simsiman, Daniel, and Chesters (1976), and the regression equation from Veith, DeFoe, and Bergstedt (1979) produced a BCF equal to 62.

Diquat is subject to photochemical degradation (Smith and Grove 1969; Simsiman, Daniel, and Chesters 1976; WSSA 1983). Zepp et al. (1975) observed a 50-percent loss in diquat within 48 hr using an ultraviolet (UV) light. Also, a diquat photodecomposition half-life of 1.6 weeks was calculated from the data presented in Smith and Grove (1969). Diquat was contained in 20-cm glass petri plates and subjected to natural sunlight. However, Simsiman, Daniel, and Chesters (1976) state that this is not a major fate process for diquat in aquatic environments. Volatilization, hydrolysis, and oxidation are insignificant fate processes (Zepp et al. 1975; Kearney and Kaufman 1976; Simsiman, Daniel, and Chesters 1976). Diquat does not have a measurable vapor pressure (WSSA 1983), nor does it have hydrolyzable substituents.

Besides sorption, microbial degradation is the major aquatic fate process affecting diquat persistence (Simsiman, Daniel, and Chesters 1976). Ultimate biodegradation half-lives, that is, biodegradation to carbon dioxide and water, were calculated from flask studies containing $^{14}C$-diquat, Lake Mendota water, and sediment (Simsiman and Chesters 1976). The aerobic half-life of diquat was 31.9 days, and the anaerobic half-life was 49.5 days. This indicates that aerobic biodegradation was more important than anaerobic biodegradation in this particular study. The QSAR biodegradation half-life was <15 days; this value compares well with the above half-lives. When these rates were coupled with sorption and any other minor fate processes, the overall diquat aqueous half-lives of 0.8 day (Frank and Comes 1967), 0.9 day (Grzenda, Nicholson, and Cox 1966), 1.6 days (Yeo 1967), and 3.8 days (Simsiman and Chesters 1976) were observed. These half-lives were calculated from the data presented in each paper and include a variety of environments and laboratory studies. However, diquat persistence in sediments can be extensive (WSSA 1983). Diquat persisted in sediments longer than 160 days after treatment in a pond study conducted by Frank and Comes (1967). Aqueous concentrations were below detectable levels within 8 days after treatment in that study.

## Endothall

Endothall (7-oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid) derivatives available for aquatic vegetation control are either potassium or amine salts. Endothall is a relatively water soluble aquatic herbicide that exhibits relatively short persistence in aquatic environments (Table 9). However, the mono (N,N-dimethylalkylamine) salt derivatives are toxic to fish at recommended application rates, and care should be taken when using these formulations where fishery resources are important (Klingman, Aston, and Noordhoff 1975). The potassium salts, in contrast, exhibit lower organism toxicity and are the preferred formulations where fish are important resources. Dissipation and persistence of endothall in aquatic environments follow similar patterns for both formulations (Pennwalt Corporation).

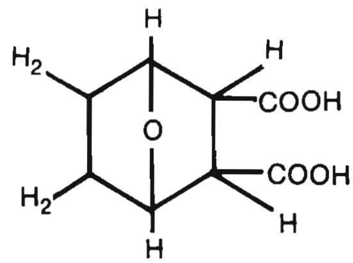
The acid form of endothall has a water solubility of 100 g/ℓ (Reinert and Rodgers 1984). The acid has a calculated $K_{ow}$ of 1.91 (Chiou et al. 1977). The dipotassium salt is soluble in water up to 1,228 g/ℓ (Reinert and Rodgers 1984) and has a calculated $K_{ow}$ value of 1.36 (Neely and Mackay 1982).

The low $K_{ow}$ values indicate that endothall would not have a significant tendency to partition to sediments. The $K_{oc}$ values for equilibrium sorption studies using the dipotassium salt were 110 and 138 for sediment-water systems from a small eutrophic pond and an oligomesotrophic reservoir, respectively (Reinert and Rodgers 1984). An overall $K_p$ value of 0.958 was calculated from this study, which compares favorably with $K_p$ values for the acid, ranging from 0.41 to 0.9, calculated from a flask system containing Lake Tomahawk water and sediment (Simsiman and Chesters 1975). A $K_p$ value of approximately 0.4 was calculated from the data presented in Sikka and Rice (1973) in which a Syracuse, NY, farm pond was treated with dipotassium endothall. Therefore, sorption would not be considered a significant environmental fate process for endothall in the environments studied.

Endothall has been shown not to bioconcentrate significantly. In laboratory and field studies, consistently low endothall levels have been observed. A BCF of 10 for endothall in mosquito fish (*Gambusia affinis*) was observed in a modified Metcalf model ecosystem (Isensee 1976). In a field study by Serns

Table 9

Structure and Environmental Properties of Endothall*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | $1.228 \times 10^6$ |
| $K_{ow}$ | 1.36 |
| $K_{oc}$ | 110-138 |
| BCF | <1 to 1.1 |
| H (atm $m^3$/mol) | Insignificant |
| Photolysis half-life, days | Stable |
| Hydrolysis half-life, days | Stable |
| Biodegradation half-life, days | 8.35 |

* Specific references and ranges are found in the text.

(1977), a 5-mg/ℓ dipotassium endothall concentration resulted in BCF values in bluegills ranging from 0.003 to 0.008. After 72 hr, fish flesh residues were not detectable. Endothall residues in caged bluegills placed in a reservoir were consistently below the minimum detectable level of 0.1 mg/kg (Reinert et al. 1985). Similar results were seen after an application of the dimethylamine salt (Waller 1963). Comparable fish BCF values calculated from regression equations were 0.65 (Neely, Branson, and Blau 1974) and 1.05 (Chiou et al. 1977).

Some organisms will exhibit temporary endothall residues that exceed the water column concentration by more than an order of magnitude. Isensee (1976) observed BCF values of 150 for the water flea, 63 for green alga (*Oedogonium*), and 36 for a snail (*Physa*); however, the endothall concentrations within the organisms were transient and were not passed along trophic levels (Pennwalt Corporation). A BCF of 0.73 was calculated for the dipotassium salt of endothall in duckweed (*Lemna minor*) using the endothall $K_{ow}$ and the regression equation found in Lockhart et al. (1983).

Volatilization, hydrolysis, and oxidation are not significant fate processes affecting the persistence of endothall in aquatic environments (Reinert and Rodgers 1984). Endothall is also not subject to photochemical degradation. In a laboratory study using the disodium salt of endothall, no degradation of endothall was observed when a UV lamp of 254-nm wavelength was employed (Mitchell 1961).

Biotransformation and biodegradation are the dominant fate processes affecting the persistence of endothall in aquatic environments (Simsiman and Chesters 1975; Holmberg and Lee 1976; Simsiman, Daniel, and Chesters 1976). A biotransformation half-life of 8.35 days was observed in a shake-flask study using three $^{14}C$-endothall concentrations and water from an oligomesotrophic reservoir (Reinert et al. 1986). Overall aqueous decay rates are considered a good estimate of endothall biotransformation because other fate processes are considered insignificant. Keckemet (1980) reported an aqueous endothall half-life of about 6.7 days after a review of the literature. The persistence of both the dipotassium and amine salts was less than 7 days in Gatun Lake, Panama Canal (Westerdahl 1983). An aqueous half-life for the dipotassium salt of 7.3 days was calculated from field studies using farm ponds (Yeo 1970). Reinert and Rodgers (1984) observed a 4.1-day aqueous endothall half-life in 133-ℓ plastic greenhouse pools containing water, sediment, and Eurasian watermilfoil. Aqueous dipotassium endothall half-lives in a marginally treated north Texas reservoir ranged from 1.1 to 1.2 days (Rodgers, Reinert, and Hinman 1984; Reinert, Hinman, and Rodgers 1988). The results presented in Holmberg and Lee (1976) compare favorably with the above aqueous endothall half-lives. A 4.1-day aqueous half-life was calculated from a Wisconsin pond treated with dipotassium endothall.

Endothall persistence in sediments ranged from 0 to 7 days in Keckemet (1980) and <4 days after a nominal 2-mg/ℓ concentration in a Texas reservoir (Rodgers, Reinert, and Hinman 1984; Reinert et al. 1985). Westerdahl (1983) observed an endothall persistence in Gatun Lake sediment of <3 days for the dipotassium salt, but <21 days for the amine salt of endothall when treated to provide a 2-mg/ℓ endothall concentration.

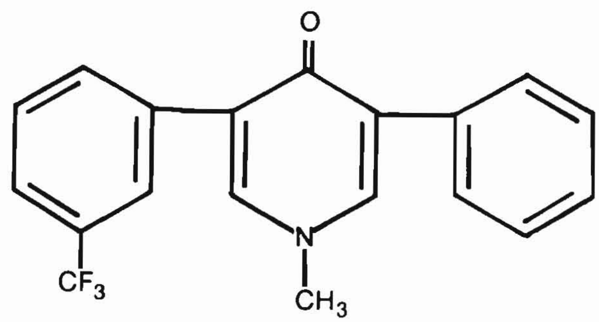
## Fluridone

Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) is a new fluorinated pyridinone-based aquatic herbicide sold as a granular or liquid form (Table 10). Fluridone has a water solubility of 12 mg/ℓ and a $K_{ow}$ of 74.1 (Elanco Products Company 1985). McCowen et al. (1979) calculated a $K_p$ value of 3.26. The $K_{oc}$ values ranged from 883 to 2,462 in a pond study in Canada (Muir et al. 1980), and a $K_{oc}$ value of 6,761 was predicted from QSAR (Hunter et al. 1984). Fluridone appeared to be tightly bound by the sediment because only 3.9 to 18.1 percent of adsorbed fluridone desorbed during a laboratory study using the same sediments as the above study (Muir et al. 1980). However, under actual field conditions, fluridone would be expected to gradually desorb from sediments and, subsequently, photodegrade in the water column (West et al. 1983).

The BCF values for fish ranged from 0.9 to 3.7 (Elanco Products Company 1985) and from 1.59 to 15.5 (West et al. 1983). Duckweed BCF values ranged from 19 to 85, and the plant BCF values were proportional to the treatment level of the pond (Muir et al. 1980). A BCF value of 1,698 was predicted by the regression equation presented in Veith, Call, and Brooke (1983). Fluridone is stable to oxidation and hydrolysis (McCowen et al. 1979). Volatilization is not expected to be a significant process; the H ranged from $1.0 \times 10^{-6}$ (Muir and Grift 1982) to $8.5 \times 10^{-5}$ atm $m^3$/mol (Hunter et al. 1984). A volatilization half-life of 49.5 days was calculated by Muir and Grift (1982).

Table 10

Structure and Environmental Properties of Fluridone*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | 12 |
| $K_{ow}$ | 74.1 |
| $K_{oc}$ | 883-6,761 |
| BCF | 0.9-15.5 |
| H (atm $m^3$/mol) | $1 \times 10^{-6} - 8.5 \times 10^{-5}$ |
| Volatilization half-life, days | 45.9 |
| Photolysis half-life, days | 1-6 |
| Hydrolysis half-life, days | Stable |
| Biodegradation half-life, days | 2-60 (based on overall half-life) |

* Specific references and ranges are found in the text.

The primary fate process affecting the persistence of fluridone in aquatic environments is photolysis (McCowen et al. 1979, West et al. 1983). A photolysis half-life of 5.8 days was observed in flasks containing pond water (Muir and Grift 1982).

Fluridone aqueous half-lives ranged from 5 to 60 days in a study by West et al. (1983), from 4 to 7 days in a Canadian pond study by Muir et al. (1980), and from 2 to 3.5 days in a Canadian pond study (Muir and Grift 1982). According to WSSA (1983), fluridone has a half-life of 21 days in water when used for control of aquatic vegetation. Sediment persistence ranged from below the minimum detectable level after 56 days in an Indiana pond (West and Parka 1981) to over 1 year in Canadian sediment (Muir et al. 1980, Muir and Grift 1982). Biodegradation is expected to occur due to the observed degradation in fish tissue (West et al. 1983) but is probably less significant than photolysis in water. However, biodegradation appears to be the major factor responsible for fluridone degradation in soils (WSSA 1983).

## Glyphosate

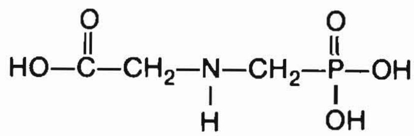
Glyphosate (N-(phosphonomethyl)glycine) is a broad spectrum herbicide employed for the control of emersed aquatic grasses, broadleaf weeds, and brush (Table 11). The isopropylamine salt of glyphosate is used for aquatic plant control and is registered for use in all types of aquatic systems.

Glyphosate has a water solubility of 12 g/ℓ (WSSA 1983), a calculated $K_{ow}$ of $5.6 \times 10^{-4}$ (Hunter et al. 1984), and a negligible vapor pressure (WSSA 1983, Brandt 1984, Hunter et al. 1984). Based on water solubility, glyphosate is not expected to bioconcentrate in aquatic biota. In controlled laboratory studies, using glyphosate concentrations 3 to 4 times the recommended levels, BCF values in fish tissue after a 10- to 14-day exposure period ranged from 0.2 to 0.3 (Brandt 1984). A BCF of 1.0 was calculated from Veith, DeFoe, and Bergstedt (1979), based on water solubility.

Glyphosate is strongly adsorbed to sediment colloids, silt, and suspended solids within the water column. Glyphosate is inactivated (no measurable phytotoxic activity) when sorbed to sediments; however, based on water solubility and $K_{oc}$, a high $K_p$ would not be expected. Because glyphosate is an acid, ionic rather than hydrophobic interactions are expected to account for the strong adsorption potential of glyphosate. A $K_p$ or $K_{oc}$ value was not

Table 11

Structure and Environmental Properties of Glyphosate*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | $1.2 \times 10^{4}$ |
| $K_{ow}$ | $5.6 \times 10^{-4}$ |
| $K_{oc}$ | High |
| BCF | Low |
| H (atm $m^3$/mol) | Insignificant |
| Photolysis half-life, days | Stable |
| Hydrolysis half-life, days | Stable |
| Biodegradation half-life, days | 60 (soil) |

* Specific references and ranges are found in the text.

found in the literature. A negligible vapor pressure supports the nonvolatile nature of glyphosate, and the tendency of glyphosate to transfer from water to the atmosphere would be negligible ( H not calculable) (WSSA 1983, Brandt 1984). Glyphosate does not contain photolyzable or hydrolyzable groups and is not expected to degrade by either route (WSSA 1983).

Biodegradation is considered the major fate process affecting glyphosate persistence in aquatic environments (WSSA 1983, Brandt 1984). Glyphosate is biodegraded both aerobically and anaerobically by microorganisms present in soil, water, and sediment. The average soil half-life is 60 days (WSSA 1983, Brandt 1984), and 90 percent of applied glyphosate is degraded within 6 months after treatment. In aquatic situations, a minimum half-life of 2 weeks has been observed. Longer half-lives (7 to 10 weeks) have been observed in non-flowing natural water systems. The QSAR estimates for aqueous biodegradation half-lives range from 2 to 15 days (Hunter et al. 1984). Glyphosate applied to two Finnish agricultural fields persisted 69 to 127 days (Muller et al. 1981). Soil organic carbon content was 44 and 1.5 percent, respectively. Loss was attributed mainly to microbial breakdown. An 8- to 19-week persistence was observed in a review of glyphosate environmental fate (Ghassemi, Quinlivan, and Dellarco 1982).

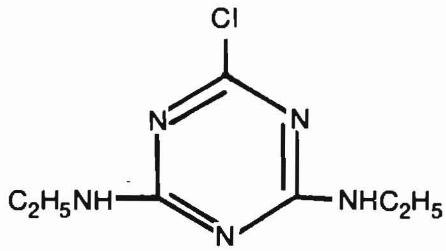
## Simazine

Simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) is a broad spectrum herbicide (Table 11). This herbicide was the first widely used triazine and is registered for use in ponds with little or no outflow (Klingman, Aston, and Noordhoff 1975). Simazine-treated water may not be used for irrigation, stock watering, and/or domestic purposes for 12 months after treatment. However, fishing and swimming are permitted immediately after treatment (Ciba-Geigy).

Simazine is soluble in water at 3.5 mg/ℓ (WSSA 1983) and has a calculated $K_{ow}$ equal to 323.6 (Hunter et al. 1984). A calculated $K_{oc}$ of 501 (Hunter et al. 1984) indicates that simazine may sorb to sediments. Glotfelty et al. (1984) also note a $K_{oc}$ of 284 in Chesapeake Bay sediments. The $K_p$ values for simazine residues in four Missouri ponds ranged from <0.17 to 1.4 (Mauck, Mayer, and Holz 1976). Simazine usually bioconcentrates by a factor of 1 or less (Mauck, Mayer and Holz 1976). However, BCF values up to 55 in fish have been measured (Ciba-Geigy), and a BCF of 38 has been calculated by the

Table 12

Structure and Environmental Properties of Simazine*

| Structure or Property | Value |
|---|---|
| Structure  | |
| Water solubility (mg/ℓ) | 3.5 |
| $K_{ow}$ | 324 |
| $K_{oc}$ | 284-501 |
| BCF | <1-55 |
| H (atm $m^3$/mol) | $9.2 \times 10^{-10}$ |
| Photolysis half-life, days | Insignificant |
| Hydrolysis half-life, days | Insignificant |
| Biodegradation half-life, days | 30-176 (based on overall half-life) |

* Specific references and ranges are found in the text.

regression equation presented in Veith, DeFoe, and Bergstedt (1979). Bioconcentration factors of 5 and 2 were measured after 28-day exposures in bluegill and catfish, respectively (Ciba-Geigy).

An H value of $3.2 \times 10^{-10}$ atm $m^3$/mol indicates that volatilization of simazine from water would be insignificant. Hydrolysis and photodecomposition are not significant simazine degradation processes (WSSA 1983). Gunther and Gunther (1970) reported a 0.013-percent loss of simazine per hour attributed to photolysis; however, this process would not be a significant fate process affecting simazine persistence.

Biotransformation is a significant process affecting simazine persistence in aquatic environments (WSSA 1983). No simazine biotransformation-biodegradation studies were found in the literature. However, simazine half-lives in four Missouri ponds calculated from the data presented in Mauck, Mayer, and Holz (1976) ranged from 46 to 174 days. Comparable half-lives were calculated from a study by Tucker and Boyd (1981) in which pond water and sediment from a southern pond were placed in 250-ml flasks, and simazine persistence was studied. According to WSSA (1983), simazine persistence in aquatic systems is dependent upon numerous factors such as algal and macrophyte infestation levels. The average aqueous simazine half-life in ponds is 30 days.

# ADJUVANTS

Adjuvants are ingredients added to a spray solution to enhance or modify the characteristics of that solution. They are designed to influence the action of, or aid in dispensing, herbicides. Adjuvants were initially developed for agricultural uses and subsequently have been adapted for noncropland and aquatic plant control as surfactants, wetting, drift control, and sinking agents. At present, over 260 adjuvants are approved for use in the United States (Thomson 1986). Table 13 includes adjuvants commonly used for aquatic plant control including general product information, ingredients, and recommendations for aquatic use by the company.

## Adjuvant Classification

Adjuvants can be grouped according to type of action: (a) activator adjuvants, (b) spray-modifier adjuvants, and (c) utility modifier adjuvants (McWhorter 1982).

### Activators

These additives primarily influence the ability of herbicides to penetrate the waxy cuticle found on most plant surfaces. The principal ingredient and carrier of herbicide spray formulations is water. Water can be repelled by the plant cuticle, limiting penetration of herbicide into the plant. Activator adjuvants, such as surfactants (surface active agents), wetting agents, and penetrants, are added to spray formulations to reduce the surface tension of water. This increases the ability of water to "wet" the plant surface and allow herbicides to readily enter the plant. Emersed and floating aquatic plants develop waxy cuticles, similar to terrestrial plants; therefore, wax penetration properties of activator adjuvants are relevant. However, submersed aquatic plants do not develop cuticles, or the cuticle is highly reduced. Therefore, the wax-penetrating properties of activator adjuvants are of little importance.

Activator adjuvants can be classified as nonionic or ionic, depending upon their ionization or dissociation in water. Nonionic agents have no particle charge, whereas ionic agents have either a positive (cationic) or negative (anionic) particle charge. It is generally recommended that cationic herbicides (e.g., diquat) not be used with anionic adjuvants and vice versa.

Table 13

Adjuvants Commonly Used with Aquatic Herbicides

| Type/Name | Company | Principal Ingredients | General Information | Company's Recommended Use |
|---|---|---|---|---|
| Activators | | | | |
| Big Wet | JLB International Chemical, Inc. | Sodium silicates | Nonionic/anionic spreader, wetting agent, penetrant | Emersed, floating |
| Cide-Kick | JLB International Chemical, Inc. | d'Limonene, selected emulsifiers 100% | Nonionic wetting agent, activator, penetrant | Emersed, floating, submersed |
| Cide-Kick II | JLB International Chemical, Inc. | d'l-Limonene, related isomers, selected emulsifiers 100% | Nonionic wetting agent, activator, penetrant | Emersed, floating, submersed |
| Ortho X-77 Spreader | Chevron Chemical | alkylarylpolyoxyethylene, glycols, free fatty acids, isopropanol | Nonionic spreader, activator | Emersed, floating |
| Spray Modifiers - Inverts | | | | |
| Asgrow "403" Invert Emulsifier | Asgrow Florida | Water-in-oil emulsifiers, selected solvents 100% | Invert emulsion, drift control, reduce evaporation, increase droplet spreading and penetration, resist washoff | Emersed, floating, submersed |

(Continued)

(Sheet 1 of 3)

Table 13 (Continued)

| Type/Name | Company | Principal Ingredients | General Information | Company's Recommended Use |
|---|---|---|---|---|
| Spray Modifiers - Inverts | | | | |
| Bivert | Stull Company | Amine salts of organic acids, aromatic acid, aromatic and aliphatic distillate 100% | Invert emulsion, chemical encapsulating, suspending agent, deposition and retention agent, reduce drift and washoff | Emersed, floating, submersed |
| I'vod Inverting Oil | JLB International Chemical, Inc. | d'Limonene, plus selected emulsifiers 100% | Invert emulsion, drift control, activator, penetrant, sticking agent | Emersed, floating, submersed |
| Spra-Mate Invert Emulsion | KDM | Fatty amine-acid salt complex 57.2% | Invert emulsion, drift control, reduce evaporation, increase droplet spreading and penetration, resist washoff. (Dilution with #2 diesel oil or xylene required) | Emersed, floating, submersed |
| VISKO-RHAP Inverting Oil | Gilmore, Inc. | Water-in-oil emulsifiers, solvents 100% (Gilmore also produces VISKO-RHAP premixed with amine or ester 2,4-D, and dichlorprop) | Invert emulsion, reduce drift. (Can be diluted with #2 fuel oil or kerosene, if necessary) | Emersed, floating, submersed |

(Continued)

(Sheet 2 of 3)

Table 13 (Concluded)

| Type/Name | Company | Principal Ingredients | General Information | Company's Recommended Use |
|---|---|---|---|---|
| Spray Modifiers - Polymers | | | | |
| Nalquatic | Nalco Chemical | Polycarboxylate polymer 30% | Improve sinking, herbicide confinement and contact properties | Submersed |
| Nalco-Trol | Nalco Chemical | Polyvinyl polymer 30% | Drift control, developed for Rodeo (glyphosate) diquat, and 2,4-D,<br>Sinking agent for Hydrothol 191 (endothall) | Emersed<br>Submersed |
| Nalco-Trol II | Nalco Chemical | Polyacrylamide copolymer 30% | Sinking agent developed for HYDROTHOL 191 (endothall) and drift control for RODEO (glyphosate) | Submersed, emersed |
| Poly Control | JLB International Chemical, Inc. | Polyacrylamide copolymer 30% | Drift control, sticking agent, anionic | |
| Poly Control 2 | JLB International Chemical, Inc. | Polyacrylamide copolymer 30% | Drift control, sticking agent, nonionic | Submersed |
| Submerge | Exacto Chemical | Polyacrylamide (polyvinyl polymer) 30% | Sinking agent, contact confinement of herbicides (manufactured in both anionic and nonionic forms) | Submersed |

(Sheet 3 of 3)

If two oppositely charged materials were mixed, chemical reactions could occur, reducing the herbicidal effectiveness of the formulation. Most activator adjuvants are nonionic types (little to no ionization in water) and can be mixed with most herbicides while remaining chemically inert. Activator adjuvants are commonly used for aquatic plant control on emersed and floating species.

**Spray-modifiers**

Spray modifiers are additives designed to confine herbicides in a material that reduces drift and allows precise herbicide placement. These adjuvants include stickers, spreaders, spreader-stickers, thickening agents, and foaming agents. Within this group, thickening agents are the most commonly used adjuvants for aquatic plant control.

Thickening agents. Thickening agents modify the viscosity or thickness of formulations to aid in dispersal, to reduce drift, and to enhance sinking. Inverts and polymers are two types of thickening agents commonly used for aquatic plant control.

Invert emulsions are prepared by mixing inverting oils with water (see "Spraying invert emulsions," p 112). The oil phase is a mixture of oil and emulsifier surfactants. Herbicides are dissolved in either the oil or water phase, based on their solubility. When properly prepared, invert formulations have a mayonnaiselike consistency and readily adhere to the surfaces of emersed and floating plants. They have the appearance of snowflakes when sprayed under the surface of the water. Flakes of invert will stick to leaves and stems of submersed plants when applied well below the surface within dense plant stands. If applied on or near the water's surface, or in thin stands of submersed plants, the invert material may rise to the surface and float.

Polymers used for aquatic plant control are designed as drift control agents and deposition aids for emersed and floating species, and as confinement and sinking agents for submersed species. Additions of 1.5 to 2 percent polymer material will produce a thick, mucuslike formulation, which will sink and attach to submersed plants.

Inverts and polymers can be advantageous for controlling emersed and floating species under certain situations (e.g., aerial applications, drift control when spraying areas adjacent to nontarget vegetation, and prevention of washoff). However, the benefits of using these adjuvants for controlling submersed plants are somewhat questionable, particularly in flowing water.

Recent studies at the US Army Engineer Waterways Experiment Station, using inverts and polymers with 2,4-D and endothall for controlling submersed plants in flowing water, suggest that at flow velocities above 3 cm/sec (0.1 ft/sec), herbicides are released from adjuvants before a lethal contact time is achieved (Getsinger and Westerdahl 1986, 1988). In contrast, some investigators have reported effective control of submersed plants with invert mixtures in still water (Bitting 1974, Baker et al. 1975).

Stickers. Stickers cause formulations to adhere to a sprayed surface and are used primarily with fungicides and insecticides, rather than herbicides.

Spreaders. Spreaders are additives that enhance coverage of formulations when sprayed on surfaces. They can increase the effectiveness of some herbicides, but are not as cost effective as most surfactants. The main use of spreaders is with wettable powder fungicides and insecticides used on fruit trees.

Spreader-stickers. Spreader-stickers are usually combinations of compounds and are used mainly with wettable powder fungicides and insecticides.

Foaming agents. Foaming agents are surfactants that are used in specialized equipment to produce foam with varying stabilities. Foams are designed to reduce drift and evaporation. Foaming agents are primarily used with herbicides in terrestrial weed control and are used less frequently than other drift control agents.

Utility modifiers. Utility modifiers are additives that expand the range of conditions under which a herbicide formulation can be used, in particular, the quality of the water (e.g., hardness, pH) used in mixing spray formulations. The primary utility modifiers consist of antifoam agents, which reduce foam in spray tanks; compatibility agents, which blend herbicide-fertilizer spray mixtures; and buffering agents, which minimize the effect of alkaline water in spray mixtures (McWhorter 1982). Utility modifiers are rarely used in aquatic plant control.

## Labels, Regulation, and Registration

Most adjuvant labels (information printed on or attached to the container) will provide information similar to that found on herbicide labels. This information usually includes: brand/trade name; ingredient statement (gives common names, sometimes chemical names, and percentages of compounds used); general information and characteristics of the product (e.g. activator, penetrant, water miscible, nonionic, compatibility, etc.); net contents; name and address of manufacturer; USEPA establishment number (identifies the production facility for tracing purposes); precautionary statements (DANGER, WARNING, or CAUTION signal words, antidotes, first aid, etc.); directions for use, storage, and disposal; and conditions of sale and warranties.

Adjuvants do not require USEPA registration under Federal law. However, no products may be used as pesticide adjuvants unless approved by USEPA. Products approved as adjuvants are listed in the Code of Federal Regulations (CFR) 40, Part 180.1001(c)(d)(e), with most of the adjuvants used for aquatic plant control listed under Subsection (d) of CFR 40, 180.1001, which states: "The following materials are exempted from the requirement of a tolerance when used in accordance with good agricultural practices as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only." Most adjuvant labels will refer to exemptions under Title 40, CFR, 180.1001(d).

Although there are no Federal requirements for adjuvant registration, several states have designated surfactant adjuvants as pesticide products, and these materials are subject to registration in those states. Users must conform with local State law when using such adjuvants.

## Adjuvant Use

When using adjuvant formulations, applicators must ensure that the herbicide is compatible with the adjuvant. If the materials are incompatible, reduced efficacy or complete failure of the treatment program may result. Also, some adjuvants require specialized spray equipment and nozzle types for correct application. Compatibility and spray equipment information can be obtained from the chemical manufacturer, if not already listed in the labeling material.

### Emersed and Floating Vegetation

Emersed and floating aquatic plants, which have portions of leaves and stems above the surface of the water, are the best candidates for herbicide/adjuvant formulations. Since adjuvants can enhance herbicide effectiveness as penetrants, wetting agents, stickers, and drift retardants when sprayed on terrestrial vegetation, they can also provide similar functions when used on air-exposed surfaces of emersed and floating aquatic plants. Applicators are constantly faced with storm events during the plant control season in most areas of the country. Adjuvants that increase herbicide penetration or allow herbicides to stick to plant surfaces can reduce washoff and increase efficacy if showers occur within 4 to 8 hr after application.

## Submersed Vegetation

Some adjuvants, particularly inverts and polymers, are advertised for submersed plant control. In theory, inverts and polymers should sink herbicides down to the target plants, thereby minimizing herbicide residues available to the environment by maintaining toxic concentrations of herbicides close to the plants. In addition, these adjuvants should increase efficacy and herbicide longevity by protecting the herbicide from environmental degradation. This would lower application costs by reducing the amount of herbicide and the number of applications required for control. Although inverts, polymers and, to a lesser extent, activator adjuvants have been used for submersed plant control for over 15 years, efficacy results have been inconsistent. Several studies have reported good control using inverts and polymers in still water (Baker et al. 1975, Adams and Baker 1979, Gates 1979), while others have reported inconsistent, or fair to poor, control (Bitting 1974, Schiller 1983, Killgore 1984).

Some inverted herbicide formulations tend to float and must be spiked with additives (e.g., salt) to achieve the desired sinking effect. If used for submersed plant control, invert formulations should be applied within the plant stand, well below the surface, with weighted hoses. This application technique will increase the ability of the invert particles to adhere to the plants and reduce the amount of floating material. Some inverting oils require the addition of xylene or fuel oil to achieve a properly blended formulation, while others do not require any additives. Invert blending information is described in the labeling material.

In most cases, polymers will deliver herbicides to target plants by acting as sinking agents. If a 1.5- to 2.5-percent polymer formulation is used, a thick, mucus-type product will be formed that will sink and cling to leaves and stems of submersed plants for at least several hours. Formulations greater than 2 percent of some polymers may clog spray nozzles and application equipment (see page 115). Formulations less than 2-percent polymer will create a relatively thin product that may not cling to leaves and stems.

Although improper spray equipment, incorrect adjuvant concentrations, and/or applicator inexperience may explain some of the inconsistent efficacy results obtained when using adjuvants for submersed plant control, the primary reason may lie in the herbicide release characteristics of adjuvant formulations. A radioisotope uptake study showed that diquat was released from an invert, into the aqueous phase, and subsequently absorbed by the submersed plant hydrilla, rather than moving directly across the invert/plant surface interface (Silver, Mansell, and Illingworth 1974). Recent studies on herbicide/adjuvant mixtures in flowing water (Getsinger and Westerdahl 1986, 1988) tend to support the work of Silver, Mansell, and Illingworth. Getsinger and Westerdahl mixed the herbicides 2,4-D and endothall with three inverts and two polymers and found that most of the herbicide was released in the first 30 min posttreatment, when the adjuvant mixtures were applied to submersed plant stands growing in flowing water.

These studies strongly suggest that even though inverts and polymers can deliver herbicide formulations to submersed plants and adhere to plant surfaces for extended periods, the herbicides themselves quickly leach from the adjuvant into the surrounding water. Thus, the effective herbicide exposure time on submersed plants with a herbicide/adjuvant formulation may not vary significantly from the exposure time obtained with nonadjuvant formulations.

# GLOSSARY

Absorption - The process by which a herbicide passes from one system into another, e.g., from the soil solution into a plant root cell or from the leaf surface into the leaf cells. Pertaining to soils, it is the incorporation or assimilation of molecules of a gas, liquid, or dissolved substance into soil particles.

Acid equivalent (ae) - The theoretical yield of parent acid from the active ingredient content of a herbicide formulation. These formulations contain a certain acid ingredient as the active toxicant. An example of this is 2,4-D.

Activator - A substance (adjuvant) that accelerates the effect or increases the total effect of a herbicide.

Active ingredient (ai) The chemical in a herbicide formulation primarily responsible for its phytotoxicity and which is identified as the active ingredient on the product label.

Acute toxicity - The quality or potential of a substance to cause injury or illness shortly after exposure to a relatively large dose. (See Chronic toxicity.)

Adjuvant - Any substance in a herbicide formulation or added to the spray tank to improve herbicidal activity or application characteristics.

Adsorption - Pertaining to soils, it is the adhesion of molecules of a gas, liquid, or dissolved substance to the surface of soil particles.

Allelopathic substances - Chemical compounds produced by plants that affect the interactions between different plants, including microorganisms.

Amphipod - Any of a large group (Amphipods) of small crustaceans with a laterally compressed body.

Anion exchange - Pertaining to soils and herbicides, it is the process whereby positively charged soil sites have an affinity for negatively charged herbicide particles and the herbicide particles are adsorbed or "tied up" on the positively charged soil sites. Anion exchange is less prevalent than cation exchange in most soils.

Antagonism - An interaction of two or more chemicals such that the effect when combined is less than the predicted effect based on the activity of each chemical applied separately.

Antidote - (1) A chemical applied to prevent the phytotoxic effect of a specific herbicide on desirable plants (synonymous with protectant); (2) A substance used as a medical treatment to counteract herbicide poisoning.

Antifoaming agents - A spray equivalent useful for suppressing both surface foam and entrained air.

Aqueous solution - A water solution resulting from the dissolution of another substance in water.

Backwater - Lenticlike water, usually less than 6 feet in depth, which is continuous with lotic water.

Band treatment - Applied to a linear, restricted strip rather than continuous over the entire treated area.

Bioassay - Quantitative determination of herbicide concentration by use of sensitive indicator plants or other biological agents.

Biota - The flora and fauna of a region.

Broadcast treatment - Applied as a continuous sheet over the entire treated area.

Canal or waterway - Man-made structure for holding or moving water. Flow can be regulated and water may be moved by gravity or pumps. Usually wide enough to allow movement of boats or barges.

Carcinogenic - Capable of causing cancer in animals.

Carrier - A gas, liquid, or solid substance used to dilute or suspend a herbicide during its application.

Cation exchange - Pertaining to soils and herbicides, it is the process whereby negatively charged soil sites have an affinity for positively charged herbicide particles and the herbicide particles are adsorbed or "tied up" on the negatively charged soil sites. Cation exchange is more prevalent than anion exchange in most soils.

Chelate - A ring structure (complex) that usually contains a metal ion held by coordination bonds with a definite number of surrounding ions, groups, or molecules. The complex remains essentially undisassociated at great dilutions.

Chemical name - The name applied to a herbicide active ingredient which describes its chemical structure according to rules prescribed by the American Chemical Society.

Chlorosis - Loss of green color (chlorophyll) from foliage.

Chronic toxicity - The quality or potential of a substance to cause injury or illness after repeated exposure to small doses over an extended period of time. (See Acute toxicity.)

Cladoceran - Any of an order (Cladocera) of minute, chiefly freshwater, branched crustaceans that includes water fleas.

Common name - An abbreviated name applied to a herbicide active ingredient usually agreed upon by the American National Standards Institute and the International Organization for Standardization.

Compatibility - Mixable in the formulation or in the spray tank for application in the same carrier without undesirably altering the characteristics or effects of the individual components.

Concentration - The amount of active ingredient or herbicide equivalent in a quantity of diluent expressed as percent, pounds per gallon, kilograms per liter, etc.

Conditional registration - The Administrator of the US Environmental Protection Agency may, under certain conditions, conditionally register a pesticide. The conditions are: (1) when the pesticide and proposed uses for it are substantially similar to any currently registered pesticide and its use, or it differs only in ways that would not increase significantly the risk of unreasonable adverse effects on the environment, and (2) when approval of the registration or amendment in the manner proposed by the applicant would not increase significantly the risk of any unreasonable adverse effect on the environment.

Contact herbicide - A herbicide that causes localized injury to plant tissue where contact occurs.

Crisis exemption - Responsible officials of Federal or State agencies can declare a crisis exemption when they have determined that crisis conditions exist. Crisis exemptions involve the emergency application of a pesticide on specific sites for control of specific pests for which it is not registered without following formal procedures in obtaining a specific exemption.

Deep channel - Lotic (flowing) waters that are greater than 6 feet in depth during most seasons; this unit may include irrigation canals.

Desiccant - Any substance or mixture of substances used to accelerate the drying of plant tissue.

Diffusion - With reference to herbicides in sediment, it is the horizontal and vertical movement of a herbicide through sediment.

Diluent - Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Directed application - Precise application to a specific area or plant organ such as to the leaves or stems of the plants.

Dispersible granule - A dry granular formulation that will separate or disperse to form a suspension when added to water.

Dissolved oxygen - A measure of the amount of the gas, oxygen, that is dissolved in water. Oxygen is required for aerobic respiration by aquatic organisms. The concentration is expressed as milligrams per liter.

Dormancy - The state of inhibited germination or plant organ growth in the presence of the required conditions for initiating growth.

Ecotype - A population within a species that has developed a distinct morphological or physiological characteristic (including herbicide resistance) as an adaptation to a specific environment and which persists when individuals are moved to a different environment.

Efficacy - The term means effectiveness and is a measure of the effectiveness of a pesticide.

Embayment - Lentic waters, including shoreline and possible open deep water, which are protected from wind and substantial wave action by protected shoreline.

Emergency exemption - Certain State or Federal Government officials may petition the US Environmental Protection Agency for specific exemptions for emergency use of a herbicide on specific sites for control of specific plants for which it is not registered, when there is a compelling need. The USEPA Administrator may grant or deny such petitions for cause. Specific exemptions are issued under prescribed time limits.

Emergence - The event in seedling or perennial growth when a shoot becomes visible by pushing through the soil surface.

Emersed plant - A rooted or anchored aquatic plant adapted to growth with most of its leaf-stem tissue above the water surface and not lowering or rising with the water level.

Emulsifier - A substance that stabilizes suspensions of droplets of one liquid in another liquid, which otherwise would not mix.

Emulsion - One liquid suspended as minute globules in another liquid (for example, oil dispersed in water).

Encapsulated formulation - Herbicide enclosed in capsules (or beads) of inert material to provide for safer handling and/or control the release of a chemical.

Epinasty - That state in which more rapid growth on one side of a plant organ or part (especially stem) causes it to bend or curl downward.

Esters - Pertaining to herbicides, esters are organic salts formed by the union of an organic acid and an organic base (an alcohol or phenol). An example is 2,4-D acid combined with isooctyl alcohol to form the isooctyl ester of 2,4-D.

EUP - EUPs (Experimental Use Permits) are issued by the Administrator of the US Environmental Protection Agency or a designated State official to permit an experimental program to accumulate registration data for a new use pattern for a pesticide. The pesticide may be a new one or one that is already registered for other uses but needs an amended registration for a new use pattern. EUPs are issued under certain specifications and limitations on use of the experimental pesticide.

Eutrophic - A body of water characterized by becoming, naturally or by pollution, rich in dissolved nutrients and often shallow with a seasonal deficiency in dissolved oxygen.

Evapotranspiration - The term means a combination of the actions of evaporation and transpiration of water from plants and nearby soils. Evaporation refers to the vaporization or passing off of water from plant surfaces and soils. Transpiration is a physiological process and refers to the evaporation or passing off of water that has originated from the leaf pores.

Extender - A chemical that increases the longevity of a herbicide.

FFDCA - Federal Food, Drug, and Cosmetic Act.

FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act.

Filamentous algae - Colonial algae that develop filaments either attached to a surface or free-floating. Generally, they are green or blue-green types.

Floating plant - A free-floating or anchored aquatic plant adapted to growth with most of its vegetative tissue at or above the water surface and lowering or rising with the water level.

Flooded structure - Lentic waters of greater than 6 feet in depth with sufficient obstructions and structure to impede navigation by all boats (e.g., flooded forest).

Flowable - A two-phase formulation that contains solid herbicide suspended in liquid and forms a suspension when added to water.

Formulation - (1) A herbicidal preparation supplied by a manufacturer for practical use; (2) The process, carried out by manufacturers, of preparing herbicides for practical use.

General use pesticide - This term is a US Environmental Protection Agency classification for pesticides that do not cause unreasonable adverse effects on the environment as defined by statute when used as directed. Applicators are not required to be certified to apply general use pesticides.

Germination - The process of initiating growth in seeds.

Granular - A dry formulation consisting of discrete particles generally less than 10 cubic millimeters and designed to be applied without a liquid carrier.

Hardness - A measure of the concentration of divalent cations (principally calcium and magnesium). Hardness is usually expressed in terms of milligrams per liter as calcium carbonate (mg/$\ell$ as $CaCO_3$).

Herbaceous plant - A vascular plant that does not develop persistent woody tissue above ground.

Herbicide - A chemical used to control, suppress, or kill plants.

Herbicide resistance - The trait or quality of a population of plants within a species or plant cells in tissue culture of having a tolerance for a particular herbicide that is substantially greater than the average for the species.

Hydrolysis - A chemical reaction in which a compound reacts with the ions of water ($H^+$ and $OH^-$) to produce a weak acid, a weak base, or both. Hydrolysis is often a factor in the degradation of herbicides.

Hydrophilic - Having a strong affinity for water.

Hydrophobic - Lacking affinity for water.

Hydrosoil - The bottom soil of a lake, pond, reservoir, stream, canal, or ditch.

Interim tolerance - As defined by statute, an interim tolerance is a pesticide residue tolerance granted by the US Environmental Protection Agency while petitions for a permanent tolerance for negligible residues of the pesticide in foods or feeds are pending and until action is completed on these petitions.

Intermittent channel - Periodic lotic waters, which may include irrigation canals and drainage ditches.

Invert emulsion - The suspension of minute water droplets in a continuous oil phase.

Invertebrate animals - The term includes all animals without a vertical column (backbone). Insects are an example.

Ions - Ions are groups of atoms having either net negative or positive charges. Positively charged ions are called cations. Negatively charged ions are called anions. Similarly charged ions repel each other. Oppositely charged ions attract each other.

IPM - The term means integrated pest management, which may consist of combining two or more pest management methods such as chemical, biological, mechanical, and cultural to minimize or prevent damage by a pest or pests.

Irrigation canal or ditch - Man-made structure for holding or moving water to be used principally for agricultural or industrial purposes. Flow can be regulated and water may be moved by gravity or pumps. Width is usually the minimum required to move the necessary volume of water (to reduce evaporation losses). This water body type includes main canals and laterals.

Isomer - A compound, radical, or ion that contains the same number of atoms of the same element but differs in structural arrangement and properties.

Labeling - As defined in the Federal Insecticide, Fungicide, and Rodenticide Act, it is the label attached to a container of a pesticide and also any written, printed, or graphic matter which accompanies the pesticide such as ads, brochures, bulletins, or pamphlets. It includes directions for using an approved herbicide.

Large reservoir - A nonflowing body of water that arises from a man-made retention structure. These reservoirs are usually greater than 1,000 surface acres in size with water retention times of months to years.

$LC_{50}$ - This is the abbreviation for the median lethal concentration of a toxicant in water or air that will kill 50 percent of an exposed population of test animals during a specified exposure time. It is often expressed in parts per million (ppm). The lower the $LC_{50}$ value, the more toxic the toxicant.

$LD_{50}$ - This is the abbreviation for the median lethal dose of a toxicant administered to a population of test animals that will kill 50 percent of them. Usually, $LD_{50}$ is expressed in terms of milligrams of toxicant per kilogram of body weight of the test animal (mg/kg). The $LD_{50}$ measures the acute oral and dermal toxicity of a chemical. The lower the $LD_{50}$, the more toxic the toxicant.

Leachability - Pertaining to a herbicide, it is a measure of the tendency, ability, or degree to which a herbicide will leach through soil. Leachability of a herbicide is dependent upon interacting soil and climatic factors.

Matrix - In terms of controlled release formulations of herbicides, it is the material into which the herbicide is impregnated for slow release.

Mesotrophic - A body of water characterized by having a moderate amount of dissolved nutrients.

Metabolism - The chemical and physical processes going on continuously in living organisms and cells, consisting of those by which assimilated food is built up into protoplasm and those by which protoplasm is used and broken down into simpler substances or waste matter with the release of energy for all vital processes. Some soil microorganisms metabolize (eat and digest) certain constituents of herbicide chemicals and break them down to simpler substances.

Metabolite - In the case of a pesticide, it is a compound resulting from metabolic action (biotransformation) upon the pesticide by a living organism. The action varies (oxidation, reduction, etc.), and the metabolite may be either more or less toxic than the parent pesticide.

Mutagenic - Capable of causing genetic changes.

Natural lake - A nonflowing body of water that arises from natural causes. Lakes may have continuous or intermittent input of water from a watershed, and they usually have a significant outflow. If sufficiently shallow, the water body may be called a marsh.

Necrosis - Localized death of tissue usually characterized by browning and desiccation.

Nonionic emulsifier - An emulsifier that does not ionize (assume a positive or negative charge) is a nonionic emulsifier. Such emulsifiers do not ionize in solution and react with mineral salts present in treated waters or waters used as diluents to cause unsatisfactory mixing of the pesticide with the water.

Nonselective herbicide - A herbicide that is generally toxic to all plants. Some selective herbicides may become nonselective if used at very high rates.

Nontarget species - Species not intentionally affected by a pesticide.

Nonvascular plants - Plants which lack a vascular (food and water-conducting) system, such as algae.

Oligotrophic - A body of water characterized by being deficient in plant nutrients having abundant dissolved oxygen with no marked stratification.

Oncogenic - Capable of producing or inducing tumors in animals, either benign (noncancerous) or malignant (cancerous).

Open deep water - Lentic (nonflowing) waters of greater than about 6 feet in depth, with no obstructions or structures closer than 6 feet to the surface.

Organelles - A specialized membrane-bound cellular part, e.g., mitochondrion, chloroplast.

Parenchyma - A soft tissue made up of thin-walled, undifferentiated living cells with airspaces between them, constituting the major internal composition of plant leaves and roots, and the central portions of stems.

Parts per million - Pertaining to applications of herbicides to water, this term has reference to parts of herbicide applied per million parts of water. It is expressed as p/mv (parts per million by volume) or gallons of herbicide active ingredient per million gallons of water, or as p/mw (parts per million by weight) or pounds of herbicide active ingredient per million pounds of water.

Pelleted formulation - A dry formulation consisting of discrete particles usually larger than 10 cubic millimeters and designed to be applied without a liquid carrier.

Persistent herbicide - A herbicide which, when applied at the recommended rate, will harm susceptible vegetation for an extended period of time. (See Residual herbicide.)

Phloem - The living tissue in plants which functions primarily to transport metabolic compounds, e.g. sugars, from the site of synthesis or storage to the site of utilization.

Photodecomposition - The degradation or breakdown of pesticide toxicants into less toxic or nontoxic compounds by the action of sunlight.

Photooxidation - Oxidation under the influence of radiant energy.

Phytotoxicity - Degree to which a material is injurious to vegetation. It is specific for particular kinds or types of plants.

Plant growth regulator - A substance used for controlling or modifying plant growth processes without appreciable toxic effect at the dosage applied.

Pond - A nonflowing body of water that may arise from natural causes or a man-made retention structure. Ponds are usually 10 surface acres or less in size and have little or no continuous outflow of water.

Postemergence (poe) - (1) Applied after emergence of the specified aquatic plant; (2) Ability to control established plants.

Preemergence (pe) - (1) Applied to the sediment prior to emergence of the specified aquatic plant; (2) Ability to control plants before or soon after they emerge.

Rate - The amount of active ingredient or acid equivalent applied per unit area or other treatment unit.

Registration - The process designated by FIFRA and carried out by the US Environmental Protection Agency by which a pesticide is legally approved for use.

Residual herbicide - A herbicide that persists in the soil and injures or kills germinating plant seedlings over a relatively short period of time. (See Persistent herbicide.)

Residue - That quantity of a herbicide remaining in water or on the soil, plant parts, animal tissues, whole organisms, and surfaces.

Restricted use pesticide - This is a US Environmental Protection Agency classification for pesticides that may cause "unreasonable adverse effects on the environment" as defined by statute, including injury to the applicator when used as directed. Applicators need certification to apply herbicides under this classification.

River - Continuously flowing body of water with intermittently variable flow rates. Rivers may vary in width from 30 to several hundreds of feet and from a few feet to greater than 10 feet in depth.

Salts - Pertaining to herbicides, salts are compounds formed by combining an organic acid with an organic or inorganic base. An example is the dimethylamine salt of 2,4-D.

Selective herbicide - A chemical that is more toxic to some plant species than to others.

Serial application - Serial application is defined as the use of one herbicide immediately or shortly after the use of another herbicide on the same site.

Shoreline - Lentic waters less than 6 feet in depth.

Small channel - Lotic waters less than 6 feet in depth during most seasons; this unit may include irrigation canals or ditches.

Small reservoir - A nonflowing body of water that arises from a man-made retention structure. Small reservoirs are usually 10 to 1,000 surface acres in size with water retention times of months.

Solubility - Solubility of a gas, liquid, or solid material in a liquid solvent is the maximum quantity of the substance that will dissolve in the solvent. Solubility varies with temperature, so usually is expressed at a standard temperature such as 25° C.

Soluble concentrate - A liquid formulation that forms a solution when added to water.

Soluble powder - A dry formulation that forms a solution when added to water.

Sorption - Sorption has reference to the action of either absorption or adsorption, or both.

Special Local Need registrations (Section 24c, FIFRA) - Designated State Government agencies are empowered to provide for additional uses of Federally registered herbicides formulated for distribution and use within that State to meet special local needs. This is done in accordance with the purpose of the Federal Insecticide, Fungicide, and Rodenticide Act if registration has not been previously denied, disapproved, or cancelled by the US Environmental Protection Agency Administrator.

Specific gravity - Specific gravity is the ratio of the weight or mass of a given volume of a substance to that of an equal volume of another substance (water for liquids and solids) used as a standard. Water has a specific gravity of 1.00 (mean sea level).

Spot treatment - A herbicide applied to restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger field.

Spray drift - Movement of airborne spray from the intended area of application.

Spreader - Spreaders are substances added to herbicides to increase the area of contact of a herbicide on a leaf or stem surface.

Sticker - Stickers are substances added to herbicides to increase the retention of sprays on plants so the spray works more efficiently.

Stolons - Stolons are the creeping, above-ground stems of certain perennial plants, also called runners.

Stream - Continuously or intermittently flowing body of water with widely varying flow rates. Streams may vary from less than 1 foot to about 30 feet in width and from less than 1 foot to a few feet in depth.

Submersed plant - An aquatic plant that grows with all or most of its vegetative tissue below the water surface.

Surfactant - A surface active agent added to a herbicide to reduce interfacial tension between the applied herbicide and the contacted surface of the target plant. This enhances the phytotoxic activity of the herbicide. Surfactants may be classified as activators, adjuvants, deflocculators, dispersants, emulsifiers, antifoaming agents, spreaders, stickers, or wetting agents, depending on their mode of action.

Susceptibility - The sensitivity to or degree to which a plant is injured by a herbicide treatment. (See Tolerance.)

Suspended solids - A measure of the nonfilterable (particulate) residue suspended in water. This measure is reported in milligrams per liter.

Suspension - A mixture containing finely divided particles evenly dispersed in a solid, liquid, or gas.

Suspension of registration - A suspension of registration is issued when the US Environmental Protection Agency Administrator determines that use of a pesticide poses an "imminent hazard" as defined by statute. Suspension means the suspended pesticide is not to be used from the date of the official suspension notice. In other words, it is an immediate action.

Synergism - An interaction of two or more chemicals that, when combined, is greater than the effect of each chemical applied separately.

Systemic action - Refers to herbicide chemicals that alter normal plant biological functions through means of certain biochemical reactions (growth, respiration, or photosynthesis are examples of some altered functions). The term systemic is associated with translocated herbicides.

Tank mix - A mixture of two or more herbicides to enhance efficacy. Tank mixes may be formulated by manufacturers or may be mixed or blended as part of the spray solution by end-users.

Technical toxicant - A pesticide in pure form (usually 95 to 100 percent active ingredient) as it is manufactured by a chemical company prior to being formulated into end-use products.

Temporary tolerance - This term refers to a residue tolerance for a herbicide established by the US Environmental Protection Agency to permit a pesticide registrant the time (usually 1 year) to collect additional residue data to support a petition for a permanent tolerance; usually associated with an EUP (experimental use permit).

Teratogenic - Capable of producing birth defects.

Tolerance - (1) Ability to withstand herbicide treatment without marked deviation from normal growth or function (See Susceptibility); (2) The concentration of herbicide residue that will be allowed in or on agricultural products.

Toxicity - The quality, degree, or state of being toxic. Toxicity is measured and quantified in terms of $LD_{50}$ and $LC_{50}$ for pesticides. (See Acute toxicity and Chronic toxicity.)

Trade name - A trademark applied to a herbicide formulation by its manufacturer.

Translocation - The term often is associated with systemic herbicides. It refers to movement or translocation of herbicides from point of contact or entry into a plant to other parts of the plant where it affects the plant's normal biological functions (systemic action). An example is translocation from leaves to roots or from roots to leaves.

Turbidity - A measure of the amount of suspended particles in water as determined by the amount of light scattered by the particles. Turbidity is reported in NTUs (nephelometric turbidity units).

Vapor drift - The movement of chemical vapors from the area of application. Some herbicides, when applied at normal rates and normal temperatures, have a sufficiently high vapor pressure to change them into vapor form, which may cause injury to susceptible plants distant from the site of application. Note: Vapor injury and injury from spray drift are often difficult to distinguish.

Vascular plants - A vascular plant possesses specialized conducting cells. The xylem transports water and the phloem transports food. These tissues are collectively referred to as the vascular system.

Volatility - A measurement of the tendency of water or other substances, such as an active ingredient in a herbicide, to vaporize into the atmosphere.

Water-miscible - A substance that has the capability of being mixed with water, such as a mixture of certain solvents and water.

Water pH - The pH of water is a measure of the hydrogen ion content. The range of pH is from 0 to 14: 7 is neutral; pH less than 7 is acid; and pH greater than 7 is basic.

Water temperature - A measure of the average kinetic energy of any aquatic system on a Celsius or Fahrenheit scale.

Weed - Any plant that is objectionable or interferes with the activities or welfare of man.

Weed control - The process of reducing weed growth and/or infestation to an acceptable or adequate level.

Wetland - Marshy habitats characterized by shallow depth, dense, often permanent vegetation (e.g., cattails - *Typha* spp.) and sometimes seasonally intermittent flooding and drying.

Wettable powder (wp) - A finely divided dry formulation that can be readily suspended in water.

Wetting agent - A substance which, when added to a liquid herbicide, increases its spreading and penetrating power by lowering the surface tension on the target plant. Effectiveness is measured by the increase in spread of a liquid herbicide over a plant surface area.

Xylem - The nonliving tissue in plants which functions primarily to conduct water and mineral nutrients from roots to the shoot.

# PART II: APPLICATION EQUIPMENT

# INTRODUCTION

Aquatic herbicides are the primary means of managing nuisance aquatic vegetation due to their relatively low cost, ease of application, and long-term control. These herbicides are available as both liquid and dry formulations. Liquids are usually a mixture of the active ingredient, solvents, emulsifiers, and other diluents. Dry formulations are primarily granules or pellets that are impregnated with the active ingredient. To ensure the maximum effectiveness and to minimize effects on nontarget organisms, all forms of herbicides must be applied as specified on the herbicide label. This can be accomplished only if the proper application equipment is used and if the equipment is calibrated.

The following sections discuss the various types of application equipment and calibration procedures.

Supplemental information provided in the appendixes may be useful in planning and implementing an aquatic plant control program (Appendix E), evaluating the economics of chemical selection (Appendix F), documenting applicator operations (Appendix G), and researching current aquatic plant management literature (Appendix H).

# EQUIPMENT SELECTION

## Liquid Formulations

The majority of aquatic herbicides are formulated as liquids. The equipment needed for applying liquids depends on which of the two methods below is used:

a. Tank mix. The herbicide and the diluent, usually water, are mixed in a tank, and the mixture is applied to the weeds.

b. Direct metering into pump suction. The herbicide is metered into the suction side of the pump at the rate needed to apply the correct amount per acre. The diluent needed to ensure adequate coverage is drawn directly from the body of water being treated.

The "tank mix" method is suitable for treating relatively small areas, or when mixing several herbicides. When large areas are treated, many find it more efficient to use the "direct metering" method to reduce the time spent refilling the tank.

Aquatic weeds are treated from boats with outboard engines, airboats, fixed-wing aircraft, and helicopters. The type of application equipment used is dictated to some degree by which vehicle is used. Aircraft are limited to the tank mix system for obvious reasons.

### Tank-mix Applications

Figure 1 shows a typical rig used to apply tank mixes from a boat. Features of the sprayer components are described below.

Figure 1. Tank-mix application rig

Tank. The boat-mounted tank, usually made of fiberglass, has a capacity of 50 to 100 gal. Usually the tank will have graduations on the side indicating the volume at that level. The tank should have a large opening for easy filling and cleaning.

Agitation system. Most liquid applicators are equipped with some type of agitation system. Good agitation is important for maintaining a uniform spray mixture and for mixing of adjuvants such as surfactants or polymers. Figure 2 shows hydraulic and mechanical agitators. Sometimes tanks are equipped with both types of agitators.

A well-designed hydraulic agitation system that uses a venturi device for stirring is adequate for keeping wettable powders in suspension. However, this type of agitator will not stir the mixture enough to form invert emulsions or mix polymers, which will be discussed in more detail later. To function properly, the hydraulic agitation line must be tapped into the high-pressure side of the pump, as shown in Figure 3. When using a hydraulic agitator, the pump must have the capacity to simultaneously deliver the required flow to the boom or hand gun and the agitator. If the maximum pressure that can be achieved after completely closing off the pressure regulator is lower than the pressure needed, the agitator orifice size will have to be reduced. Mechanical or paddle wheel agitators are probably the best type of agitator. Well-designed mechanical agitators stir the mixture vigorously and allow the use of both polymers and invert emulsions. Sometimes a clutch is added to the agitator drive, and the operator can keep the mixture at the desired consistency by agitating only when needed.

Hoses. The inner and outer layers of all hoses should be resistant to the chemicals used. Check with the chemical and hose supplier if there is any doubt, because a hose weakened by chemicals might leak or burst unexpectedly. Two materials widely used for hoses are ethylene vinyl acetate (EVA) and ethylene propylene dione monomer (EPDM).

A pressure hose must be strong enough to withstand the maximum pressure within its length without bursting. Pressure varies at different points along the hose, with the greatest pressure occurring at the pump. Hose size is important because the pressure loss in the hose depends on the hose inside diameter (ID), length, and the flow rate. Figure 4 shows the pressure losses that occur in various size hoses depending on the flow rate.

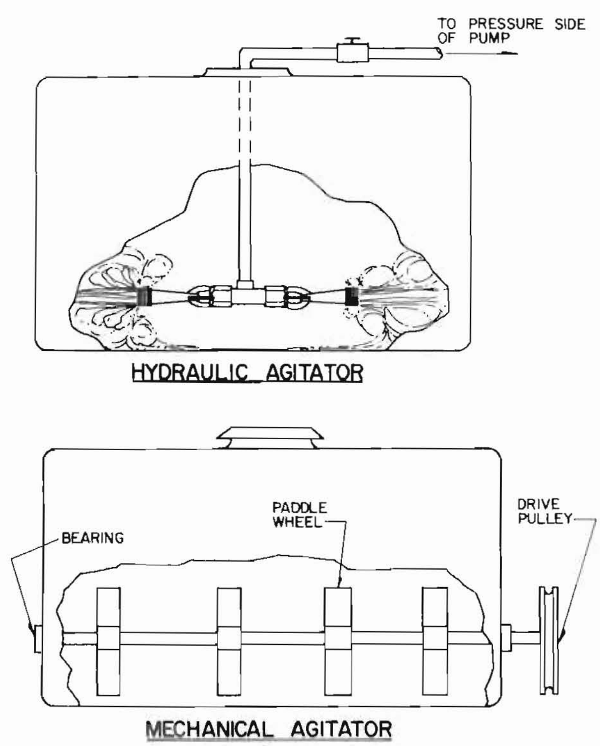



Figure 2. Agitation systems

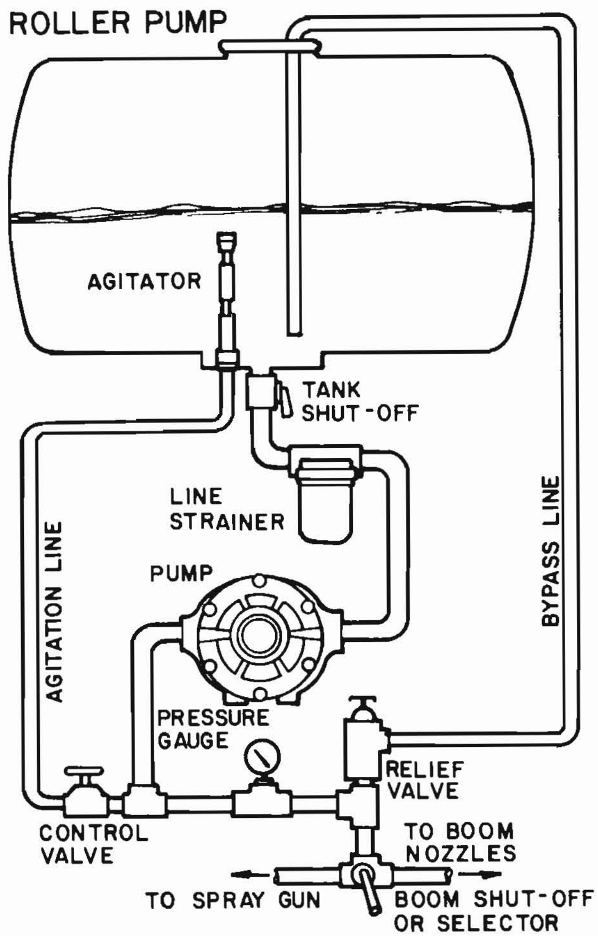



Figure 3. Roller pump system

For example, a 1/2-in. ID hose losses 1 psi per foot at a flow rate of 10 gal per/min.

Pressure loss in relatively short hoses is not very important, but it is important to choose the proper hose size when extremely long hoses are used, such as in some hand-gun spraying work. Recommendations for hose sizes are presented in the tabulation that follows.

| Pump output gpm | Hose Size: Suction, in. | Hose Size: Pressure, in. |
|---|---|---|
| ≤12 | 3/4 | 5/8 |
| 12-25 | 1 | 3/4 |
| 26-50 | 1-1/4 | 1 |

Suction hoses are under a partial vacuum. Thus, they will not burst, but they can collapse. Choose a suction hose that is reinforced to prevent collapsing. A collapsed suction hose can restrict flow of liquid and "starve" a pump, causing decreased outflow and greatly accelerated wear. As a rule of thumb, suction hose diameters should be at least as large as the pump inlet port.

Polyvinyl chloride (PVC) pipe works well for rigid plumbing; however, caution should be used in selecting the valves. For example, a 1-in. valve can be plumbed to a 1-in. pipe; yet, the opening inside the valve may be restricted to 0.5 in. in diameter.

Pumps. Most of the pumps used for applying liquids for controlling weeds are of five general types: roller, piston, centrifugal, diaphragm, and gear. Each type has certain capabilities and limitations that determine when it should be chosen. Characteristics of the various pumps are as follows.

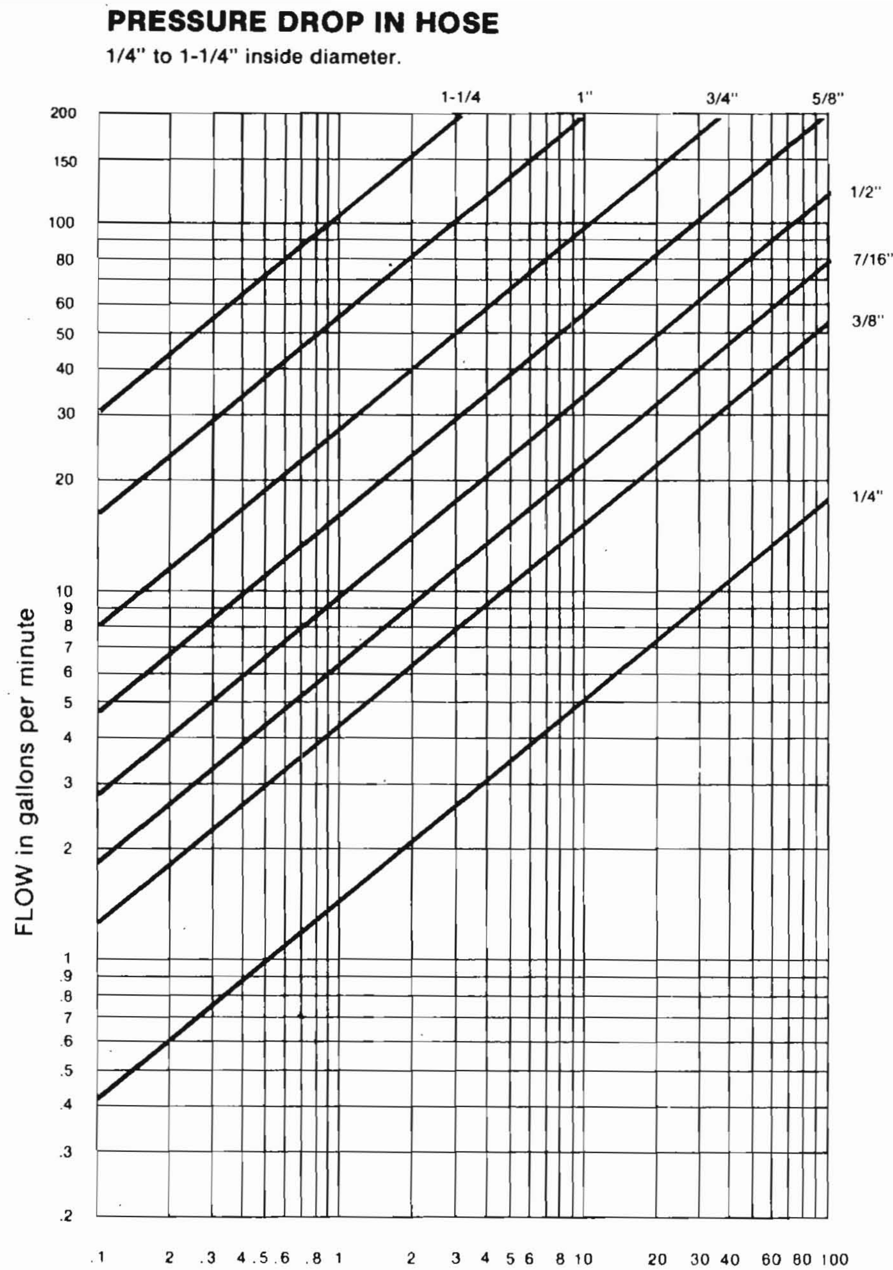



Figure 4. Pressure drop in hoses

| Pump | Capacity gpm | Speed rpm | Maximum Pressure psi | Material That Can Be Sprayed |
|---|---|---|---|---|
| Roller | 0-35 | 600-2,600 | 300 | Nonabrasive |
| Piston | 0-60 | 500-1,800 | 1,000 | Abrasive |
| Centrifugal | 0-150 | 600-6,000 | 70 | Abrasive |
| Diaphragm | 1-60 | 200-1,200 | 850 | Abrasive |
| Gear | 5-20 | 500-1,800 | 100+ | Nonabrasive |

Roller. An advantage of roller pumps is that they are relatively inexpensive. They are widely used in agriculture on general-purpose crop sprayers. However, roller pumps are not often used for aquatic weed control work because high pressure is needed for hand-gun spraying. Even though a pressure capability of 300 psi is stated for a roller pump (see tabulation above), which is adequate for hand-gun spraying, the pump would not be able to sustain high pressure very long because the rollers wear and fluid leaks back past the rollers. Figure 3 shows how to plumb a liquid application system using a roller pump. The system has a hydraulic agitator that would only be suitable for systems not used to apply invert emulsions or sprays containing polymers.

Piston. Piston pumps are often used in aquatic weed control because they can deliver high pressure for hand-gun spraying. These pumps are dependable, long lived, and highly adaptable to most types of service. Their primary disadvantages are that they are expensive and deliver relatively low volume, although the volume is usually sufficient for aquatic applications.

A piston pump is a positive displacement pump, which means that the output depends on the displacement of the piston in the cylinder. Output is proportional to speed and virtually independent of the pressure needed to force the flow through the orifice area on the system.

Output from a piston pump is not steady. It comes in spurts because the distance that the piston travels in the pump cylinder varies with time. This problem can be eliminated through the use of a surge dampener. Pulsation is especially noticeable for pumps with a small number of pistons (many small pumps have two pistons). The pulsing nature of the flow makes it desirable to install a surge tank into the plumbing system. The system should also be equipped with a glycerine-filled pressure gauge because glycerine dampens movement of the gauge needle. These gauges last longer and can be read more easily than nondampened gauges on piston pump-equipped systems.

Figure 5 shows how to plumb a system equipped with a piston pump. The system includes an unloader valve that is especially useful when spraying with a hand gun. When the gun is shut off, the system pressure rises until it is sufficient to overcome the spring force on the unloader valve. The valve will crack open and bypass fluid back to the tank. Without the unloader valve, the pressure would continue to rise until a hose bursts. The plumbing system shown in Figure 5 is appropriate for all of the positive displacement pumps, including diaphragm and gear pumps as well as the piston type.

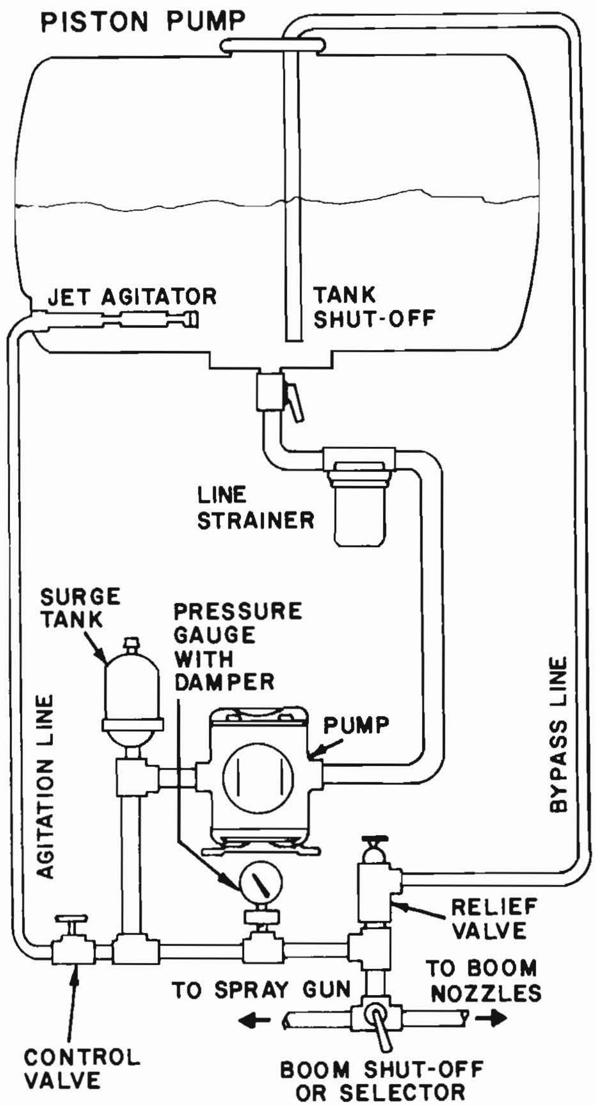



Figure 5. Piston pump system

Centrifugal. Centrifugal pumps deliver very high flow rates when working against a low pressure. These pumps are especially useful for transferring fluids from one tank to another or from the body of water into the tank when refilling.

Centrifugal pumps are not suitable for most systems used in aquatic weed control because of the inability to generate high pressures. Small centrifugal pumps that are coupled to a small two-stroke cycle engine are sold by some manufacturers and are particularly useful for tank refilling.

Diaphragm. Diaphragm pumps have been popular in Europe for some time and are now used in many applications instead of piston pumps. Benefits of diaphragm pumps include relatively low cost, low maintenance, and small size compared with other pumps with similar flow and pressure ratings. Like piston pumps, diaphragm pumps are positive displacement pumps. Therefore, the pump output depends on pump speed and remains constant regardless of the pressure it is working against.

Gear. Gear pumps are used in a number of applications and are positive displacement pumps capable of high pressures. The corrosive chemical comes in contact with the pumping gears, so maintenance can be a problem. Gear pumps are becoming less popular and are being replaced by diaphragm and piston pumps in many installations.

Nozzles. The spray nozzle performs three basic functions: forms the spray pattern, determines the droplet size, and meters the herbicide flow rate. Numerous types of nozzles are used in terrestrial weed control. Nozzle selection is based on a balance of these three functions. However, due to the nature of aquatic weed control, the variety of nozzles used in aquatic spraying is much less. The type of application (submersed or surface) determines the nozzle type selected. The four primary application methods and nozzle considerations in aquatic weed control are:

a. Hand-gun spraying of surface, emersed, and ditchbank species: Hand guns are equipped with nozzles that provide a high flow rate (3 to 6 gal/minute), a straight stream, and a large droplet size. This arrangement ensures thorough wetting of the target vegetation with minimum spray drift.

b. Subsurface injection just below the water surface for submersed weed control: Usually five short hoses are spaced at approximately 2-ft intervals on a short, bow-mounted boom. Hoses are just long enough to place the nozzle at the water surface or just below it (Figure 6). The nozzle body contains a disk that meters the flow into the water.

c. Bottom placement or deep-water injection: Nozzles are located at the end of long hoses that trail from a boom on the bow of the boat. Hoses are usually weighted to keep the herbicide placement deep within the weed mat or near the bottom (Figure 7). A common arrangement involves constructing a nozzle by drilling small holes in a piece of galvanized pipe. The length of the pipe depends on how much weight is needed to lower the pipe into the thick weed beds. Pipe length varies from 9 to ≥30 in. The pipe is capped on one end and attached to the hose on the other. Deep-water injection hoses must not have any clamps or protrusions that will catch and hold plants.

d. Aerial applications: Aerial applications normally use hollow cone or flat fan nozzles to improve coverage with the smaller volume of spray solution applied per acre. A specialized aerial boom designed to produce a large droplet size at low pressure and low volume is the microfoil boom.

Nozzle and/or metering disk wear is a problem that can affect calibration and cause the application of too much herbicide per acre. Because some nozzle types wear more than others, it becomes necessary to calibrate the system more frequently or change nozzles. The primary types of nozzle tips include:

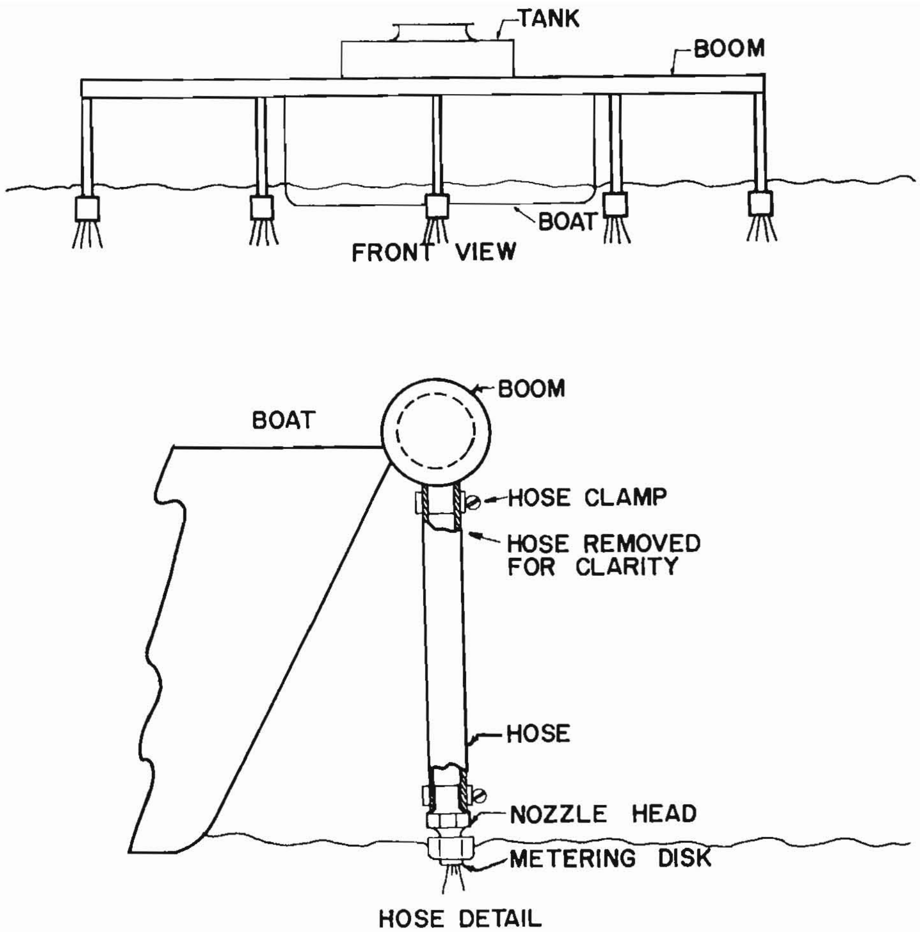



Figure 6. Surface injection system

(a) brass, (b) stainless steel, (c) hardened stainless steel, (d) nylon, and (e) ceramic. Hardened stainless steel and ceramic nozzles are the least prone to wear and are worth the extra expense.

## Direct Metering into Pump

When large areas are treated, it is often more efficient to meter the herbicide into the suction side of the pump and eliminate the time spent mixing tanks. Water is drawn into the pump through "water boxes" built into the bottom of the spray boat (Figure 8). Normally one or more plastic tubes are tapped into the pump suction line. Each tube has a valve for opening and closing the lines. Tubes have an "in-line" orifice used to meter the correct amount of herbicide into the system. Figure 9 shows how a typical herbicide withdrawal hose is constructed.

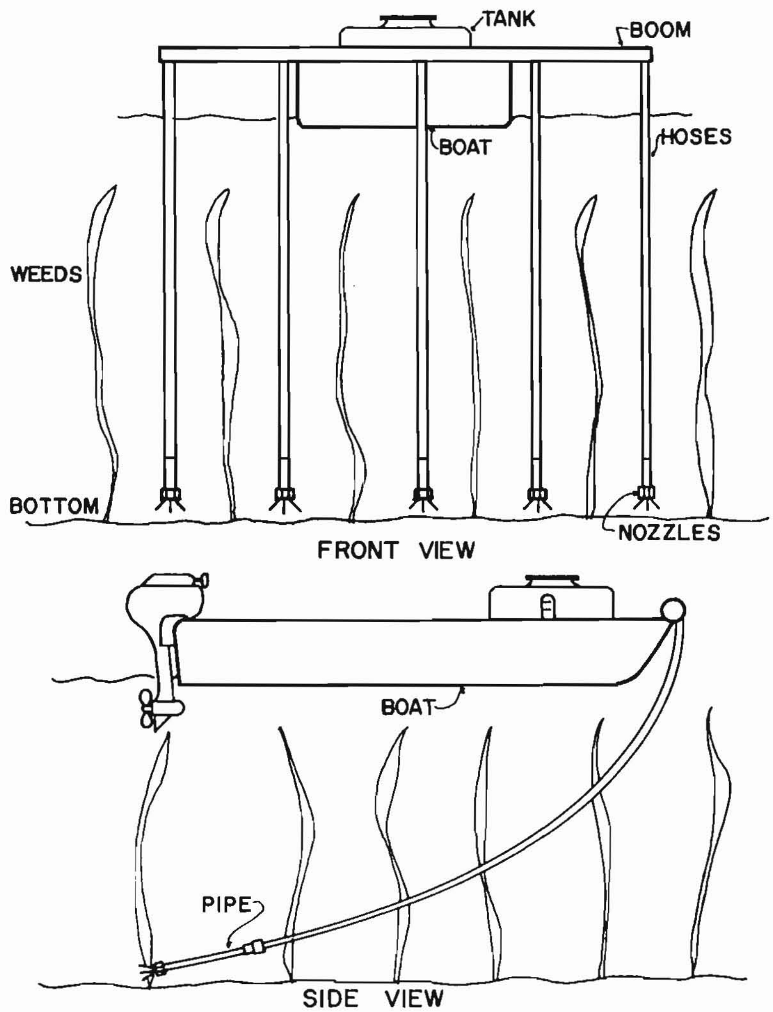



Figure 7. Deep-water injection system

A number of suction hoses can be used so that the application can continue without interruption. When the herbicide in the container being used is depleted, the applicator opens a valve in the hose that is in a second container and closes the valve of the empty one.

Other than not using a tank and having the previously described equipment on the suction side of the pump, equipment used for spraying in this manner is very similar to tank-mix units.

Spraying invert emulsions. An invert emulsion contains water droplets dispersed in a continuous oil phase. This is contrasted to a normal emulsion, which is oil droplets dispersed in a continuous water phase. Invert

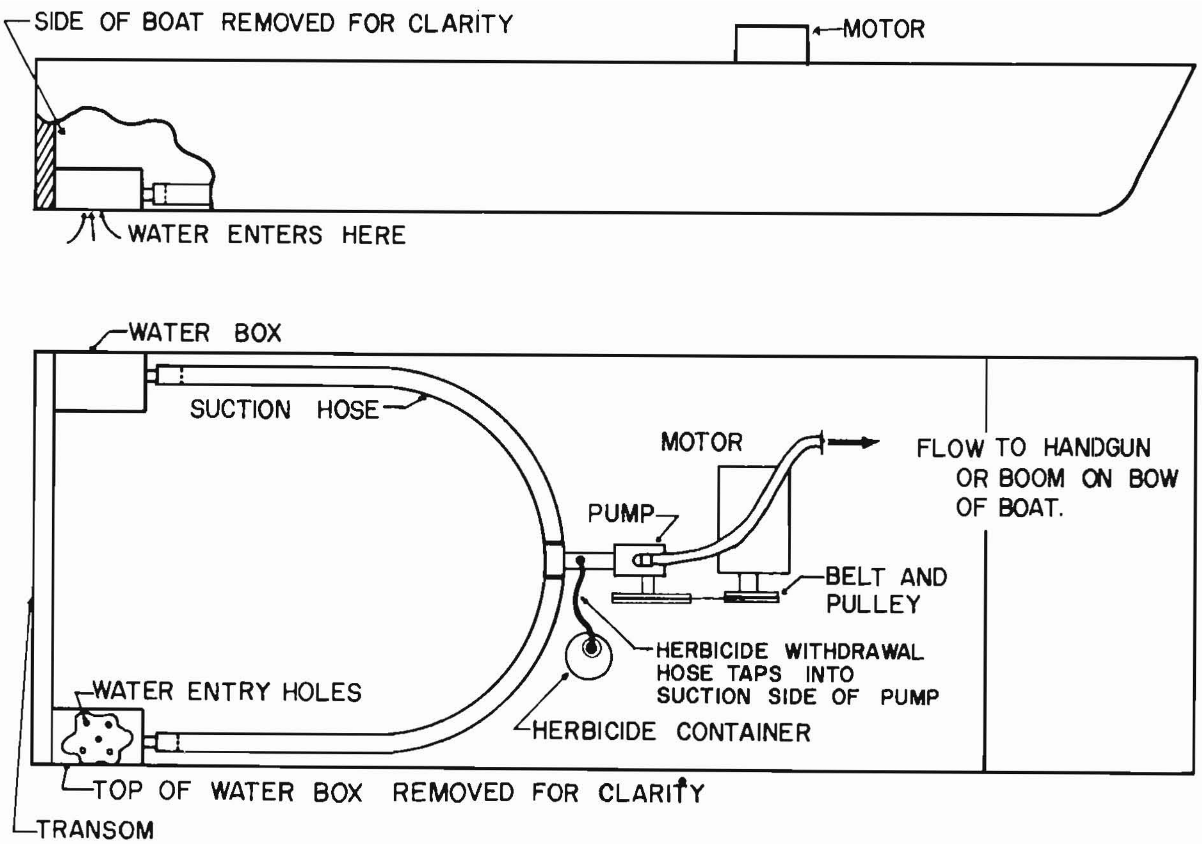



Figure 8. System for withdrawing herbicide directly from its container and water from the body of water treated

emulsions, which are a thick mayonnaise-like material, do not generate as many fine droplets as water-based sprays, and the emulsion adheres to the target vegetation. Invert emulsions are often used as a carrier for herbicide sprays when working in areas where spray drift would be especially detrimental.

Both "tank-mix" and "suction side metering" equipment can be used for applying an invert emulsion. Generally, about 5 parts of diesel fuel and 1 part of emulsifying agent are mixed together. This mixture is then mixed with water in the ratio of 15 parts of water to 1 part of oil-emulsion. These proportions are only given as an example because some applicators use xylene as the oil rather than diesel. Also, some inverting oils do not require mixing with xylene or fuel oil. The proportions differ with the oil and emulsifying agent used.

When mixing the invert in a tank, the ingredients are added to the tank and the vigorous stirring of a good mechanical agitator causes the formation

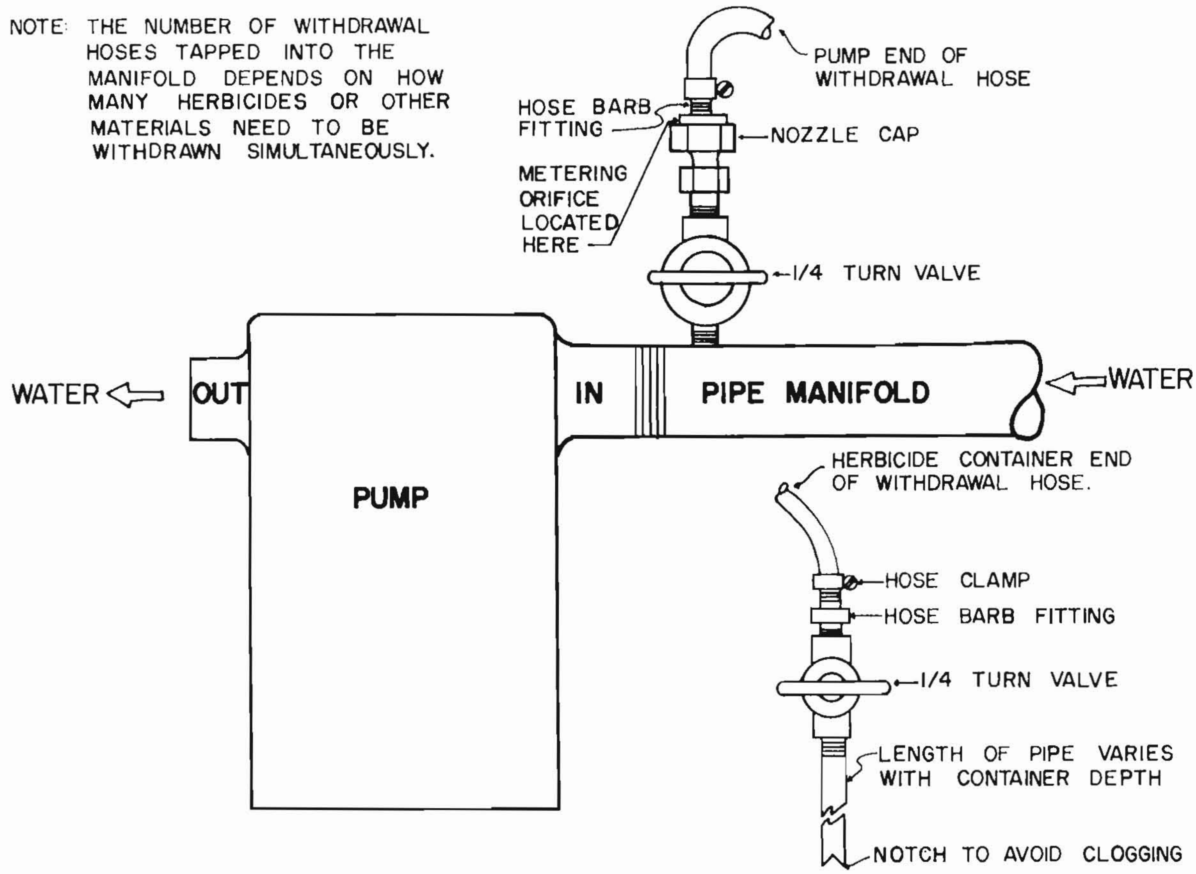



Figure 9. Plumbing detail of herbicide withdrawal hose

of the emulsion. If there is no tank, a mixture of the oil and emulsifier is metered into the pump's suction line in the right proportion. Water, oil, and emulsifier then pass through the pump and into a mixing unit that vigorously stirs the mixture and forms the invert emulsion. There are at least two types of mixing units. One is a power-driven unit that does the mixing in a manner similar to household mixers. The other type unit has baffles similar to an exhaust muffler. Ingredients mix because of the turbulence caused by changing directions as the liquid flows through the unit.

This description of invert application greatly simplifies the procedures of using an invert. Invert pumps and systems are generally expensive, must be kept airtight, and extensive experience is required to set up a trouble-free system. It is highly recommended that anyone anticipating setting up an invert system should visit, observe, and learn the nuances of the procedure from an agency that regularly uses invert applications.

Applying sprays containing polymers. Polymers are long-chain carbon molecules which, when united with water, thicken the solution. They can be added to a spray mixture to reduce the number of fine droplets generated, thereby reducing the potential for herbicide drift onto nontarget plants. This is especially helpful when spraying surface weeds with a hand gun.

Polymers are also useful when spraying submersed weeds with the nozzles located below the water surface. Usually, about 0.5- to 2-percent polymer is gradually added to the tank mixture or is metered into the spray suction, depending on the system being used. Often the stream that comes from the nozzle under the surface resembles a string. The "polymer string" containing the herbicide settles onto the weeds and disperses downward within the weed mat adhering to the plant material. Using this type of application it is possible to treat the submersed weed mat using less herbicide than needed when adding enough herbicide to bring the total water volume to a phytotoxic concentration level.

Applicators may find that the output from their sprayer will diminish greatly when spraying with 1- to 2-percent polymer. Often the reason given for the flow reduction is that the water-polymer mixture flows less readily, and the pump is unable to force the material through the nozzles. Usually this is not the reason for the reduced flow.

Positive displacement pumps normally used in aquatic weed spraying have the capability to force any amount of material that enters the pump out of the pump. If the engine speed (rpm) is set by a governor, as are most small gas engines that power sprayer pumps used in aquatic weed spraying, the output will be the same for a viscous liquid as it would be for water, assuming the same amount entered the pump. The difference is that the pressure required to force the viscous liquid through the discharge hose would have to be greater. More pressure means the engine has to deliver more horsepower.

Output reduces when using these high concentrations of polymer because the amount entering the pump suction is reduced. Tests show that the flow rates of water and water-polymer mixtures through a given nozzle at a given pressure vary little. Most of the flow reduction is because the pump is "starved" on the suction side. A system used to apply water-polymer mixtures should have extra-large suction lines with a minimum of fittings between the tank and pump inlet.

## Granular Formulations

Granular herbicides are normally applied with a bow-mounted centrifugal or blower-type spreader (Figure 10). Centrifugal spreaders can treat a wide swath when relatively large granules are used. The ability to treat a wide swath (30 to 40 ft) without requiring any type of structure extending beyond the sides of the boat makes granular application attractive. The disadvantage is the large quantity of material (100 to 400 lb/acre) that must be handled. The rotor that slings the granules is driven by a 12-volt DC motor. Normally the spreader is bought as a complete unit except for the mounting system. Since boats used to treat aquatic weeds are normally used to apply both sprays and granular applications from the bow, the spreader is usually mounted so that it can be quickly removed. The spreader in Figure 10 is stabilized using chains and turnbuckles.

Blower-type spreaders use air pressure generated by a "squirrel cage" fan to propel the granules. This avoids dust created from the mechanical rotor, which sometimes crushes the granules.

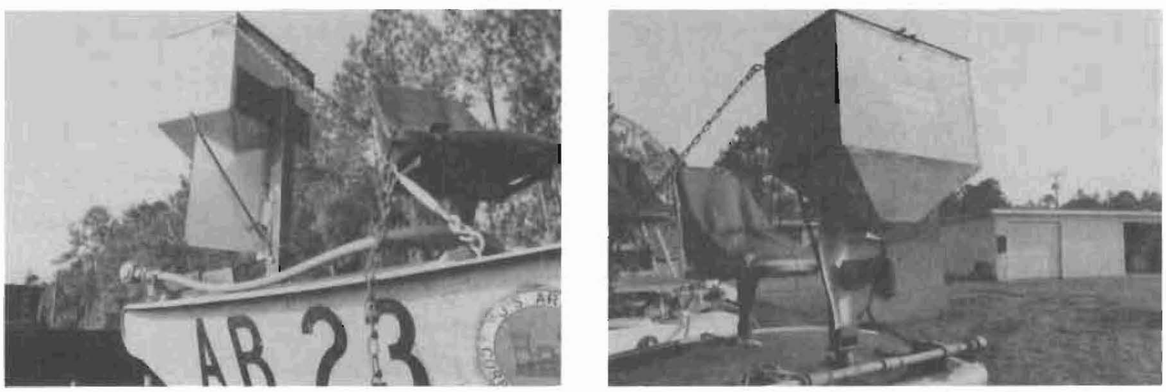


Figure 10. Granular spreader

# EQUIPMENT CALIBRATION

Herbicides must be applied at some particular rate per acre for them to be effective. Desired rate per acre is given on the herbicide label. Applying the material at a lesser rate could result in poor weed control, while a greater rate would, at least, be more costly and could possibly result in serious environmental damage (e.g., fish kills).

Output of the sprayer or spreader is independent of acreage being covered by the unit. It is the job of the equipment operator to coordinate the output and acreage covered to obtain the correct rate of application. The finest boat, equipped with the finest sprayer, cannot compensate for a poor operator that either will not, or cannot, properly calibrate his equipment. However, a knowledgeable operator can in many instances compensate for equipment shortcomings.

## Liquid Formulations

### Determining Gallons per Acre Applied

Gallons per acre (GPA) must be determined to know the number of acres that a tank of given volume will cover. Once the acres per tank are known, the applicator can mix in the amount of chemical recommended on the label, usually in pounds or liquid ounces per acre.

The GPA applied is the result of two factors: the gallons per minute (GPM) output of the nozzles and the acres per minute covered by the sprayer. Knowing these two factors, the GPA can be determined from:

$$\text{Gallons per acre} = \frac{\text{Gallons per minute}}{\text{Acres per minute}}$$

The GPA can be changed by changing the GPM, the acres per minute, or both.

Varying GPM. The GPM from the nozzles can be varied by (a) increasing or decreasing the opening in the pressure regulator, (b) changing the size or number of nozzles, or (c) in some instances, changing the size of the pump. Essentially, the two methods used to change nozzle flow when calibrating equipment are to (a) change the size or number of nozzles for larger changes and (b) change the pressure regulator opening for small changes.

Pump output flows through the regulator and the opening in the nozzles. Reducing the size of the regulator opening requires a greater pressure to force the pump output through the system. Greater pressure increases the flow from the nozzles. Greatest flow from the nozzles and highest pressure occur when the regulator is completely closed off and all of the pump output flows from the nozzles. Enlarging the regulator opening results in a lower pressure and lesser flow through the nozzles. Flow changes induced by varying the regulator opening are generally small because flow through an orifice varies as the square root of the pressure (flow will only double when pressure is increased four times).

Determining GPM. The three commonly used methods for determining the GPM being delivered are:

a. Measure the amount of liquid needed to restore the level in the tank after running the equipment for a measured length of time.

b. Catch the flow for a measured length of time from each nozzle on the boom and add them to determine the total GPM.

c. Time how long it takes for the tank level to drop from one volume graduation to another. The difference in graduations would give the gallons delivered. Divide this amount by the time in minutes to determine GPM.

Method b above is the preferred method. It can give a quick, accurate value for GPM and provides a check on nozzle flow uniformity. Even though nozzle uniformity is not as critical in aquatic weed control as it is in terrestrial spraying, nozzles emitting approximately 15 percent from the average should be changed. The example below demonstrates checking for uniformity and determining GPM.

Example 1. A boat is equipped with a boom that has five nozzles. The data below were gathered by catching the flow from each nozzle for 30 sec. What is the GPM, and is the nozzle uniformity sufficient?

| Nozzle | Ounces caught in 30 sec |
|---|---|
| 1 | 64 |
| 2 | 36 |
| 3 | 40 |
| 4 | 45 |
| 5 | 30 |
| | Total = 215 |

$$\text{Average} = \frac{215}{5} = 43$$

If 15 percent is considered the allowable range, determine the range by multiplying the average by 1.15 and 0.85.

Top of allowable range = $1.15 \times 43 = 49.5$

Bottom of allowable range = $0.85 \times 43 = 36.6$

Nozzle 1 is outside the range on the high side, and nozzles 2 and 5 are outside the range on the low side. These three nozzles should be rechecked and changed if the amount caught is the same as in the first test. The GPM delivered by the five nozzles before changing the two is determined as shown:

Total ounces per minute = $2 \times 215 = 430$ oz/min

$$\text{GPM} = \frac{430 \text{ oz/min}}{128 \text{ oz/gal}} = 3.36 \text{ gal/min}$$

Note. The total ounces caught was doubled to get ounces per minute because the nozzle tests were for 30 sec. The time period of the test depends on the orifice size and the capacity of the container used to catch the flow. It should not be less than 30 sec for the sake of accuracy.

When using method a to determine GPM, one third to one half of the tank volume should be sprayed to achieve reasonable accuracy. Method c depends on the graduations on the tank being correct. They should be checked by pouring known amounts into the tank and observing whether the level is at the proper graduation.

Varying acres per minute. The equipment's swath width and forward speed determine the acres per minute covered. Once a boom length is selected and mounted on the boat, the swath width is set for that particular unit. When spraying with a hand gun, the swath can be varied considerably. Forward speed can be varied within a relatively narrow range. Normally the speed is 3 to 4 mph when treating with an airboat at idle speed. Airboat speed can easily be determined by measuring the time required to travel a known distance, at a constant revolutions per minute. This knowledge can be used to establish or "lay out" treatment plots.

Determining the acres per minute. The formula for calculating acres per minute is shown below.

$$\text{Acres/min} = \frac{\text{Swath width (ft)} \times \text{Speed (mph)} \times 88}{43{,}560}$$

where

88 ft/min = 1 mph

43,560 sq ft = 1 acre

This equation can be simplified to:

$$\text{Acres/min} = \frac{\text{Swath width (ft)} \times \text{Speed (mph)}}{495}$$

Example 2. An airboat is equipped with a 100-gal tank and a boom with hoses spaced 30 in. apart. What is the GPA applied by the boat, and how much chemical recommended at 1 gal/acre should be added when filling the tank?

a. Determine GPM. Assume the operator had the tank filled to the 100-gal mark and ran the unit until the level was 50 gal. If it took 11.3 min to spray the 50 gal, the GPM is:

$$\text{GPM} = \frac{\text{Gallons sprayed}}{\text{Time}} = \frac{50}{11.3} = 4.42 \text{ gal/min applied}$$

b. Determine acres/minute. The operator must determine the swath and speed of the boat.

$$\text{Swath} = \text{Number of hoses} \times \text{Spacing (ft)}$$

$$5 \times \frac{30}{12} = 12.5 \text{ ft}$$

To determine speed, the operator should set out two stakes a minimum of 100 ft apart (200 ft would be better) and time how long it takes in minutes to travel the staked distance. Assuming it takes 0.36 min:

$$\text{Feet per minute} = \frac{\text{Staked distance (ft)}}{\text{Time}} = \frac{100}{0.36} = 278$$

To change a speed given in feet per minute to miles per hour, divide the feet per minute by 88.

$$\text{mph} = \frac{278}{88} = 3.2$$

Knowing both swath and speed, the operator can determine acres per minute:

$$\text{Acres/min} = \frac{\text{Swath} \times \text{Speed}}{495} = \frac{12.5 \times 3.2}{495} = 0.081$$

c. Determine GPA. Knowing GPM and acres/min, the GPA can be determined.

$$\text{GPA} = \frac{\text{GPM}}{\text{acres/min}} = \frac{4.42}{0.081} = 54.6$$

d. Determine acres covered per tank load.

$$\text{Acres/tank} = \frac{\text{Gallons/tank}}{\text{Gallons/acre}} = \frac{100}{54.6} = 1.83$$

e. Determine the chemical to add to a full tank. The label recommended 1 gal/acre, so:

$$\text{Chemical/tank} = \text{acres/tank} \times \text{rate/acre}$$

$$1.83 \times 1 = 1.83$$

The tank would have 1.83 gal of herbicide, and the remainder of the 100 gal would be water.

Note. A stopwatch graduated in minutes, tenths of minutes, and hundredths of minutes should be used for calibrating sprayers. A watch of this type is not very expensive. It is recommended because the numbers taken directly from the watch can be used in the calibration equations. In the above example, the operator was assumed to have this type of watch, and the time to spray 50 gal in part a of the example was 11.3 min. Three-tenths of a minute is 0.3 × 60 = 18 sec. If the operator had used his regular wrist watch or a stopwatch graduated only in minutes and seconds, he would have read 11 min and 18 sec as the time. He would then have to divide 18 seconds by 60 to get the decimal equivalent of 18 sec. This is not a difficult thing to do, but the right type of stopwatch would eliminate a potential source of error.

## Calibrating Flow Rate from Herbicide Container

When this type of system is used for treating large bodies of water, the gallons per acre of diluted herbicide being emitted by the nozzles is not as important as it is when applying a tank mix. What is important is the flow rate from the herbicide container. The flow rate in GPM must be coordinated with the acres per minute being covered by the equipment in order to apply the gallons per acre rate recommended on the label.

Example 3. A boat draws its diluent from the body of water being treated, and the herbicide is drawn into the suction line directly from the herbicide container. The label on the herbicide recommends 2 qt/acre. If a hand gun is being used and the operator sweeps through a 20-ft-wide swath while traveling 3 mph, at what rate should the herbicide be drawn from the container to apply the recommended amount?

a. Determine acres/minute.

$$\text{Acres/min} = \frac{\text{Swath} \times \text{Speed}}{495} = \frac{20 \times 3}{495} = 0.12$$

b. Determine GPM. In this example the required gallons per acre rate is known to be 0.5 gal/acre (2 qt = 0.5 gal). The GPM to be drawn from the herbicide container is determined as shown:

$$\text{GPM} = \text{GPA} \times \text{acres/min} = 0.5 \times 0.12 = 0.06$$

In many cases this rate would be more useful in ounces per minute for the remainder of the calibration procedure.

$$\text{Ounces/minute} = 0.06 \times 128 \text{ oz/gal} = 7.68$$

A metering orifice would be placed in the suction line as shown in Figure 11. Metering orifices made by the nozzle manufacturers for metering nematicides and fertilizers in agronomic crops are often used. There is a small difference in consecutive sizes, making accurate calibration possible, and they are inexpensive.

Immerse the suction tube into a graduated container of water and draw from the container until the system stabilizes (Figure 12). Timing of the drawdown would begin at one of the major graduations on the container. If the water level in the container of Figure 12 was somewhere between 48 and 40 before the system stabilized, the person performing the calibration would begin timing the drawdown at 40. Assuming it took 1.85 min to drop the level from 40 to 16, the rate would be 24/1.85 = 12.97 oz/min.

Figure 11. Metering orifice

The calculated ounces per minute needed to get the recommended 2 qt/acre in the example was 7.68, so the metering orifice in the system is too large. A smaller orifice should be placed in the suction line, and the process repeated until the correct ounces per minute is achieved.

Since water is often used for conducting the initial calibration instead of the herbicide actually being applied, it is especially important to note the drawdown rate during the beginning of the treatment in the field. If the flow through the orifice were considerably different from that of water, the orifice size would have to be changed.

## The 1/28th-acre Method

If a gallon is applied uniformly to an area equal to 1 acre, 1 oz would be applied to an area that is 1/128 acre, since there are 128 oz in 1 gal. If 20 gal were applied to the acre, the 1/128th-acre area would have 20 oz applied to it. By spraying an area equal to 1/128 acre and catching the spray that would have been applied to it, the ounces caught will be equal to the GPA. An area equal to 1/128 acre is 43,560/128 = 340 sq ft. The course length to spray to equal 340 sq ft depends on the width of the course. Course width depends on how the spray is applied.

When the spray is applied with a boom, with equally spaced nozzles along the boom, course width would be the nozzle spacing on the boom

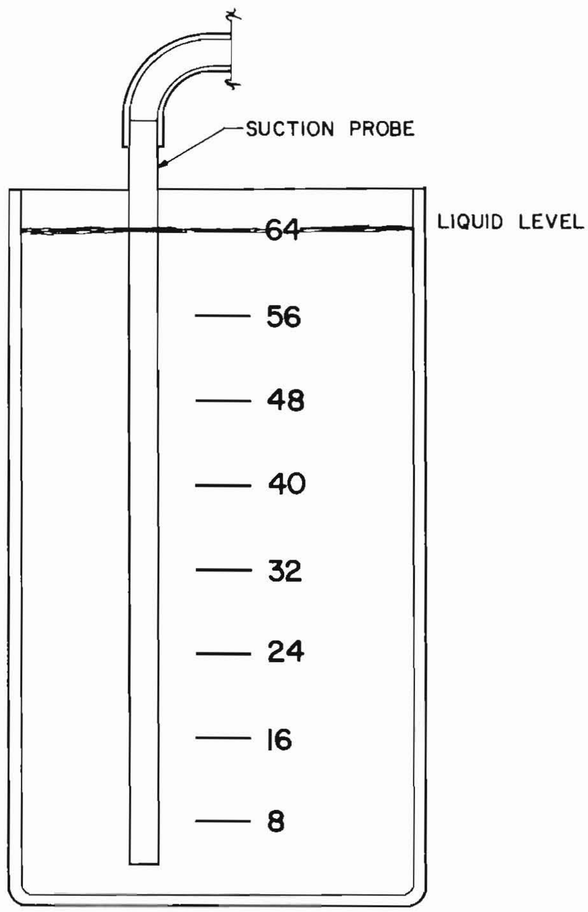



Figure 12. Graduated calibration container

expressed in feet. Course width is equal to the swath being sprayed when using a hand gun.

Course length is found by dividing the width into 340 sq ft. Figure 13 shows the course lengths to be sprayed for two conditions.

When using this calibration method in the field, the operator would set two stakes the length of the course apart in the body of water being treated. Stakes should be in an area where the vegetation is similar to that in the area to be sprayed. Time needed to travel the course length should be determined in both directions and averaged.

The operator would then catch the flow from one of the nozzles on the boom for the same time that it took for the boat to travel the course length. The nozzle chosen for the catch test should be the one nearest to the average flow rate determined from a nozzle uniformity check. A uniformity check should be part of any calibration, regardless of what calibration method is used. The example below demonstrates the 1/128 acre procedure.

Example 4. A lake is being treated with a boat equipped with a boom that has six nozzles spaced 30 in. apart. The spray tank holds 100 gal, and the herbicide is recommended at 1 gal/acre. How much herbicide should be added to the tank when mixing a full load of spray?

a. Determine course width. The width is the nozzle spacing or 30/12 = 2.5 ft.

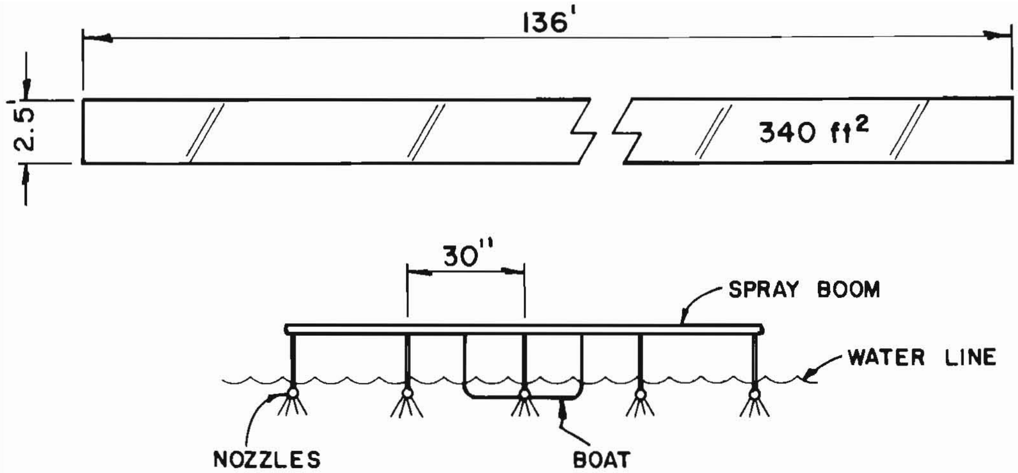
b. Determine course length. Divide the course area (340 sq ft) by the width.

$$\text{Course length} = \frac{340}{2.5} = 136 \text{ ft}$$

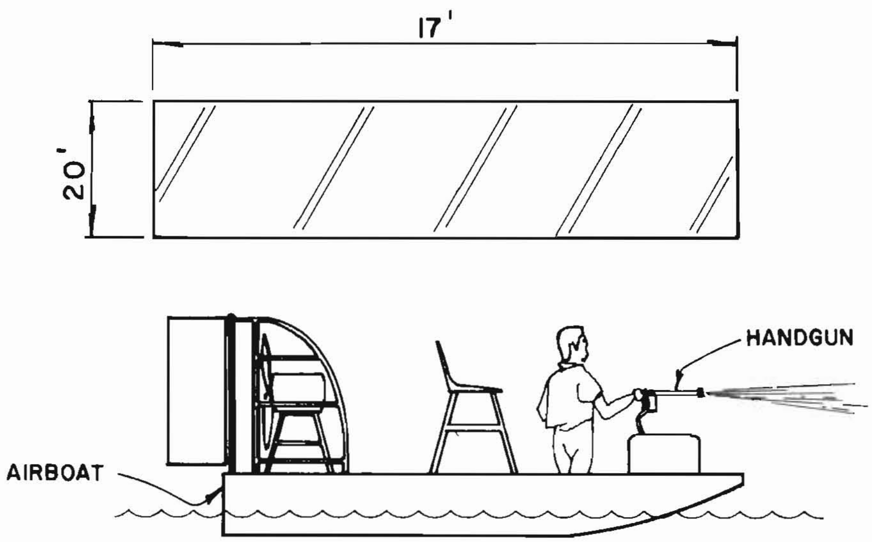
c. Set two stakes 136 ft apart and determine the time required to travel the distance. Assume it takes 0.45 min in one direction and 0.51 min in the other direction.

$$\text{Average time} = \frac{0.45 + 0.51}{2} = \frac{0.96}{2} = 0.48 \text{ min}$$

d. A uniformity check run on the six nozzles for 30 sec each gave these results: 54, 69, 59, 64, 56, and 68 oz. The average of these is 61.6. If ±20 percent is considered acceptable, the range would be




CONDITION 1: SPRAYING WITH A BOOM MOUNTED ON A BOAT




CONDITION 2: HANDGUN SPRAYING

Figure 13. Length of a 1/128-acre course

from 1.15 × 61.6 to 0.85 × 61.6, or from 70.8 to 52.4 oz. All of the nozzles fall within this range, so none would have to be changed.

The flow from the nozzle that emitted 64 oz is the nearest to the average. Flow from this nozzle would be caught for 0.48 min (the time to travel the 1/128-acre course length), and the ounces caught would be equal to the gallons per acre rate. In the field, there would be no need for additional computation, but for this example, we must mathematically determine what would have been caught in the container during the 0.48 min.

The nozzle that will be used for the test emitted 64 oz in 30 sec, so it would deliver 128 oz in 1 min. The amount caught in 0.48 min would be 0.48 × 128 = 61.4 oz. This indicates that the sprayer is applying 61.4 gal/acre.

e. Determine acres covered by a full tank:

$$\text{Acres/tank} = \frac{\text{Tank volume (gal)}}{\text{gal/acre}} = \frac{100}{61.4} = 1.63$$

f. Determine the amount of herbicide to add:

$$\begin{aligned}\text{Herbicide/tank} &= \text{amount recommended/acre} \times \text{acres covered/tank}\\ &= 1 \text{ gal/acre} \times 1.63 \text{ acres/tank}\\ &= 1.63 \text{ gal/tank}\end{aligned}$$

When the course width is very wide, e.g., when sweeping through a wide swath with a hand gun, the course length required to treat 1/128 acre is very short. Condition 2 (Figure 13) considered a swath of 20 ft, resulting in a course length of 17 ft. It would be difficult to accurately determine the time to travel between two stakes only 17 ft apart. It is best to use a course containing 10/128 acre when the spray swath is wide. Course length would be determined by dividing 3,400 sq ft by the spray swath. Course length would be 170 ft if the swath was 20 ft, as in Condition 2.

Flow from the spray gun would be caught for the period of time that it took to travel the 10/128-acre course, and the ounces caught would be divided by 10 to determine the GPA rate. Since you simply move the decimal one place to the left to divide by 10, this simplifies the computation.

Example 5. The amount of flow from the spray gun caught during the time it took to travel a 10/128-acre course was 647 oz. What is the GPA rate?

The GPA rate is the ounces caught while spraying 1/128 acre. So, GPA is determined by moving the decimal one place to the left.

GPA = 64.7, or 64.7 gal/acre

The following tabulation gives the course lengths that are equal to 1/128 acre and 10/128 acre, depending on the course width.

| Course Width, in. | Course Width, ft | Course Length, ft | |
|---|---|---|---|
| | | 1/128 acre | 10/128 acre |
| 12 | 1.0 | 340 | -- |
| 18 | 1.5 | 227 | -- |
| 24 | 2.0 | 170 | -- |
| 30 | 2.5 | 136 | -- |
| 36 | 3.0 | 113 | -- |
| 42 | 3.5 | 97 | -- |
| 48 | 4.0 | 85 | -- |
| 60 | 5.0 | 68 | -- |
| 120 | 10.0 | -- | 340 |
| 180 | 15.0 | -- | 227 |
| 240 | 20.0 | -- | 170 |

## Granular Formulations

The equation for determining pounds per acre of herbicide applied by a granular spreader is as follows:

$$\text{Pounds per acre} = \frac{\text{Pounds per minute}}{\text{Acres per minute}}$$

The equation is essentially the same as the one for liquids except pounds replace gallons in the above equation. Acres per minute is determined from the width of swath covered by the granules and the speed of the vehicle applying the granules. Example problems in granular applicator calibration are presented at the conclusion of Part II.

## Determining Pounds per Minute

Pounds per minute being spread can be determined by any of the methods described below:

a. Pour granules into the spreader hopper to some easily repeatable level. Run the spreader for a measured period of time and weigh the amount of granules needed to bring the level back to the initial point. To obtain pounds per minute, divide the pounds of granules needed to restore the level by the time in minutes that the spreader was run.

b. Pour a known weight of granules into the hopper and time how long it takes to empty the hopper. Divide the weight by the time.

c. Place a plastic bag around the spreader's spinner and run the spreader for a timed period. Weigh the bag to determine the pounds of granules caught and divide the weight in pounds by the time in minutes to get pounds per minute. This method requires that you be especially careful to keep the bag and your fingers away from the spreader spinner.

## Determining Acres per Minute

Acres per minute is a function of swath width and forward speed of the spreader. Swath width treated by a granular spreader varies considerably with the type of granule being spread. Large granules treat a wider swath than small ones. The only accurate method to determine swath width would be to lay some trays having the same area across the width of the spreader swath on 2- to 3-ft centers. After running the spreader for a long enough period to collect a "weighable" sample from each tray, the weights should be plotted on graph paper. The amount in the trays in the middle of the swath will usually be fairly constant, but at the ends the amount will taper to zero. Effective swath of the spreader will be the distance between the two points at each end of the pattern where the amount applied has tapered to about one half the amount in the middle of the pattern.

Because subsequent swaths cannot be spaced accurately when treating aquatic weeds in most instances, an approximate swath width can be determined that should be sufficient. This approximate swath can be determined by running the spreader while the boat is close to the shore and marking the place where the granules fall into the water at the extreme edges of the pattern. Distance between the pattern extremities would be multiplied by 0.80 to approximate the effective swath.

Speed of the applicator is determined as discussed in the section on calibrating liquid applicators.

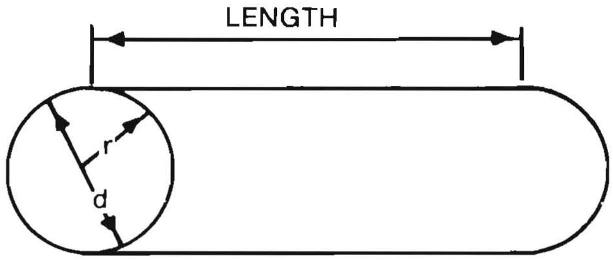
A number of useful equations and additional calibration-related problems are presented in the following sections.

## Useful Equations

- $\text{Gal/acre} = \dfrac{\text{gal/min}}{\text{acres/min}}$
- $\text{Pounds/acre} = \dfrac{\text{pounds/min}}{\text{acres/min}}$
- $\text{Acres/min} = \dfrac{\text{Swath(ft)} \times \text{Speed(mph)}}{495}$
- 2.7 lb active ingredient (ai)/acre-ft = 1.0 ppmw
- $\text{Acres per tank} = \dfrac{\text{tank volume(gal)}}{\text{gal/acre}}$
- Herbicide formulation per tank
  = acres/tank $\times$ recommended rate per acre
- for lakes: acre-feet = area(acres) $\times$ average depth(ft)
- for canals: acre-feet

  $$= \frac{\text{length(ft)} \times \text{width(ft)} \times \text{average depth(ft)}}{43{,}560\ \text{ft}^2\text{/acre}}$$
- for canals: acre-feet

  $$= \frac{\text{length(miles)} \times 5{,}280\text{(ft/mile)} \times \text{width(ft)} \times \text{avg. depth(ft)}}{43{,}560\ \text{ft}^2\text{/acre}}$$
- $\text{Acreage (rectangle)} = \dfrac{\text{length(ft)} \times \text{width(ft)}}{43{,}560\ \text{ft}^2\text{/acre}}$
- $\text{Acreage (circle)} = \dfrac{\pi d^2}{4 \times 43{,}560}$ or $\dfrac{\pi r^2}{43{,}560}$ where d and r are in feet
- $\text{Gallons of herbicide concentrate required} = \dfrac{\text{Weight required in mixture}}{\text{Weight ai/gallon of herbicide}}$
- Volume of a rectangular tank($ft^3$)
  = length(ft) $\times$ width(ft) $\times$ depth(ft)
- Volume of a rectangular tank(gal)
  = length(ft) $\times$ width(ft) $\times$ depth(ft) $\times$ 7.48(gal/$ft^3$)
- Volume of a cylindrical tank(gal)
  = area of the circular end $\times$ length $\times$ 7.48(gal/$ft^3$)




r = radius

d = diameter

area of circular end ($ft^2$) = $\pi r^2$ where r is in feet

- Speed(mph) = $\dfrac{\text{ft/min}}{88}$
- Swath width = nozzle spacing(ft) × number of nozzles
- Gal/min = $\dfrac{\text{Gallons needed to restore tank level}}{\text{Time that the sprayer was run(min)}}$
- Gal/min = $\dfrac{\text{oz/min}}{\text{128 oz/gal}}$

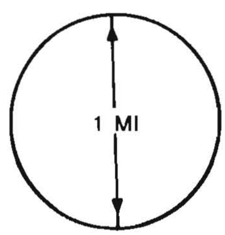
## Example Problems

Problem 1: A lake that is approximately round has a diameter of 1 mile. The average depth is 14 ft. If the lake is to be treated with 0.5 ppmw active ingredient (ai) of a herbicide, how much active ingredient is needed?

Solution:

Lake area = $\pi r^2$

= $\pi(0.5)^2$ = 0.785 square mile




Diameter = 1 mile

Radius = 0.5 mile

Area in acres = 0.785 square mile × 640 acres/square mile = 502.4

Acre-feet = Area (acres) × Depth (ft)

= 502.4 × 14 = 7,034 acre-ft

To determine how much active ingriedient is needed to yield 1 ppmw, multiply the acre-feet in the body of water by 2.7.

$$\text{ai needed for 1 ppmw} = 2.7 \times 7{,}034 = 18{,}992 \text{ lb}$$

Since only 0.5 ppmw was wanted in the lake, it would take only one half as much.

$$\text{ai needed for 0.5 ppmw} = \frac{18{,}992}{2} = 9{,}496 \text{ lb}$$

Problem 2: The herbicide used to treat the lake in problem 1 is formulated as a 50-percent WP. It is to be applied by a helicopter equipped with a suspended hopper. The centrifugal spreader at the base of the hopper covers an effective swath of 30 ft. Assuming that the aircraft speed is 40 mph, what should the flow rate from the hopper be in pounds per minute?

Solution: The ai needed was 9,496 lb from Problem 1.

$$\text{Formulation needed} = \frac{9{,}496}{0.50} = 18{,}992 \text{ lb}$$

The 18,992 lb of formulation should be evenly distributed over the lake area. The pounds per acre would be:

$$\text{Pounds/acre} = \frac{\text{Pounds of formulation}}{\text{Area (acres)}} = \frac{18{,}992}{502.6} = 37.8 \text{ lb/acre}$$

The general equation for calibration problems dealing with dry formulations is:

$$\text{Pounds/acre} = \frac{\text{Pounds/min}}{\text{Acres/min}}$$

Pounds/acre is known and acres/min can be determined because the swath and speed are known. Pounds/min can be determined by rearranging the equation to the form that follows:

$$\text{Pounds/min} = \text{Pounds/acre} \times \text{Acres/min}$$

$$\text{Acres/min} = \frac{\text{Swath} \times \text{Speed}}{495} = \frac{30 \times 40}{495} = 2.42$$

$$\text{Pounds/min} = 37.8 \times 2.42 = 91.5$$

Problem 3: An applicator draws his herbicide into the suction side of his spray system. The herbicide is recommended at 3 qt/acre. If the boat travels at 4 mph and the spray boom covers a swath of 10 ft, what is the ounces per minute that should be drawn from the herbicide container?

Solution:

$$\text{Gal/acre} = \frac{\text{Gal/min}}{\text{Acres/min}}$$

$$\text{Gal/acre} = \frac{3 \text{ qt/acre}}{4 \text{ qt/gal}} = 0.75$$

$$\text{Acres/min} = \frac{\text{Swath} \times \text{Speed}}{495} = \frac{10 \times 4}{495} = 0.0808$$

The gallons per minute that must be drawn into the pump suction in order to apply 3 qt/acre when covering 0.0808 acre/min is:

$$\text{GPM} = \text{gal/acre} \times \text{acres/min}$$

$$= 0.75 \times 0.0808 = 0.0606 \text{ gal/min}$$

$$\text{oz/min} = 128 \text{ oz/gal} \times 0.0606 \text{ gal/min} = 7.76 \text{ oz/min}$$

Problem 4: How long would it take to empty a 5-gal can of herbicide using the rate from problem 3?

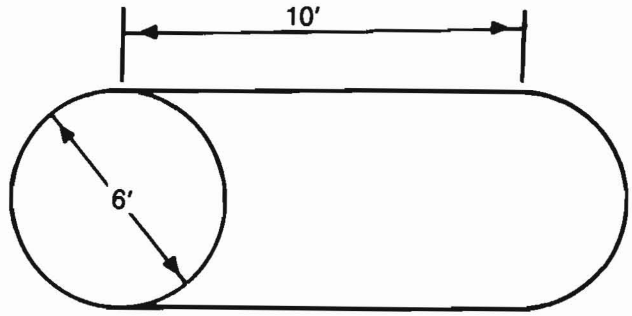
Solution:

$$\text{Ounces/5 gal} = 5 \times 128 \text{ oz/gal} = 640$$

$$\text{Time to empty 5 gal} = \frac{640 \text{ oz/5 gal}}{7.76 \text{ oz/min}} = 82.5 \text{ min/5 gal}$$

Problem 5: A water management district buys a herbicide in bulk at $10/gal. How much would it cost to fill their storage tank that is 6 ft in diameter and 10 ft long?

Solution:




Area of the circular end = $\pi r^2 = \pi 3^2 = 28.3\ ft^2$

Volume = area of circular end × length × 7.48($gal/ft^3$)

= 28.3 × 10 × 7.48 = 2,117 gal

Cost = 2,117 gal/tank × $10/gal = $21,170/tank

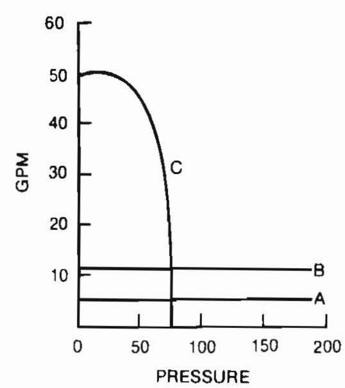
Problem 6: An applicator applies 100 GPA to some waterhyacinths while covering 0.1 acre/min. Of the pumps for which performance curves are shown, which pump could be used for this job if 100 psi pressure is used?

Solution:

To choose a pump, you need to know the GPM that must be delivered to perform the spray job and the pressure used.

GPM = GPA × acres/min

= 100 × 0.1 = 10 GPM




Since the pump must deliver 10 GPM when working against a pressure of 100 psi, the only pump that could be used (of the three whose curves are shown) would be pump B. Pump C will not generate 100 psi at all, and A delivers only about 5 GPM.

Problem 7: How long would it take to refill a 100-gal tank with pump C in the previous problem?

Solution:

When refilling, the discharge would be wide open and the pressure would be essentially 0. This pump delivers 50 GPM when working against a 0 pressure.

$$\frac{\text{Time to refill}}{\text{100-gal tank}} = \frac{\text{100 gal/tank}}{\text{50 gal/min}} = \text{2 min/tank}$$

Problem 8: A boom has five hoses and nozzles. If a 30-sec test at each nozzle showed the following results, would any of the nozzles need changing if it were decided to tolerate ±10-percent variation from the average?

| Nozzle | Ounces Caught in 30 sec |
|---|---|
| 1 | 21.0 |
| 2 | 18.2 |
| 3 | 19.3 |
| 4 | 21.2 |
| 5 | 17.2 |

Avg = 96.9/5 = 19.38

Solution:

10% of the average = $0.1 \times 19.38 = 1.938$ or 1.94

Since the allowable range is plus or minus 10 percent, 1.94 should be added and subtracted from the average to determine the range.

Greatest amount allowable = 19.38 (average)
+ 1.94 (10% of avg)
21.32

Least amount allowable = 19.38
- 1.94 (10% of avg)
17.44

Allowable range: 21.32 → 17.44. Any nozzle that falls within this range need not be changed. The only nozzle that should be changed is No. 5 because it emitted less than 17.44.

Problem 9: All five hoses from a boom are placed into a container and run for 1 min. If the container had 4 gal after the trial, what GPA is being applied by a boat when the speed is 3 mph and the hoses are spaced 2.5 ft apart?

Solution:

$$\text{GPA} = \frac{\text{GPM}}{\text{acres/min}}$$

$$\text{GPM} = \frac{\text{Gallons in container}}{\text{Length of test (min)}} = \frac{4}{1} = 4 \text{ GPM}$$

$$\text{acres/min} = \frac{\text{Swath} \times \text{Speed}}{495}, \text{ where: Swath} = \text{No. nozzles} \times \text{Spacing} = 5 \times 2.5 = 12.5$$

$$= \frac{12.5 \times 3}{495} = 0.076$$

$$\text{GPA} = \frac{4}{0.076} = 52.6 \text{ GPA}$$

Problem 10: A helicopter is applying granular herbicide at the rate of 50 lb/acre. A centrifugal spreader suspended under the craft has a capacity of 1,000 lb. If the spreader swath is 30 ft and the helicopter flies at 50 mph, how long does it take to empty a load?

Solution:

$$\text{Pounds/min} = \text{lb/acre} \times \text{acres/min}$$

$$= 50 \times \frac{30 \times 50}{495} = 151.5$$

$$\text{Time to empty spreader} = \frac{1{,}000 \text{ lb/spreader load}}{151.5 \text{ lb/min}} = 6.6 \text{ min/spreader load}$$

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# APPENDIX A: HERBICIDE MANUFACTURERS

Note: This listing does not include all suppliers of the herbicide products. Consult one of the listed manufacturers for the nearest supplier in your area.

# HERBICIDE MANUFACTURERS

## Acrolein

Magna Corporation
Pacheco and Gosford Roads
Bakersfield, CA 93311

## Complexed Copper

Applied Biochemists, Inc.
5300 W. County Line Rd.
Mequon, WI 53092
(414) 242-5870
1-800-558-5106

Kocide Chemical Corp.
12701 Alameda Rd.
Houston, TX 77045
(713) 433-6404

## 2,4-D

Rhone-Poulenc Ag Company
Research Triangle Park, NC 27709

Velsicol Chemical Corporation
World Headquarters
341 E. Ohio
Chicago, IL 60611
(312) 670-4500

InterAg, Inc.
5100 Poplar Ave., 24th Floor
Memphis, TN 38137
(901) 767-6851

## Dicamba

Velsicol Chemical Corporation
(see 2,4-D)

## Dichlobenil

Uniroyal Chemical Company, Inc.
World Headquarters
Middlebury, CT 06740

## Diquat

Applied Biochemists, Inc.
(see Complexed Copper)

Valent USA Corporation
(formerly Chevron Chemical Co.)
P.O. Box 5458
Fresno, CA 93755

## Endothall

Pennwalt Corporation
Ag Chemical Division
3 Parkway
Philadelphia, PA 19102
(215) 587-7219

## Fluridone

Elanco Products Company
Division of Eli Lilly Company
Lilly Corporate Center
Indianapolis, IN 46285
(317) 276-3636

## Glyphosate

Monsanto Chemical Co.
800 N. Lindbergh Blvd.
St. Louis, MO 63167
(314) 694-1000

## Simazine

Ciba-Geigy Corporation
PO Box 18300
Greensboro, NC 27419
(919) 292-7100

# APPENDIX B: SUMMARY OF FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT

SUMMARY OF FIFRA

All pesticides produced and distributed in the United States are regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended by the Federal Environmental Pesticides Control Act of October 1972 and the FIFRA Amendments of 1975 and 1978 (Arbuckle et al. 1983;* 7 U.S.C. 135 et seq.; Public Law (PL) 92-516, 86 Stat. 973, October 21, 1972; PL 94-140, 89 Stat. 751, November 28, 1975; and PL 95-396, 92 Stat. 819, September 30, 1978). FIFRA provides for a balance between the risk involved with the pesticide use and the benefits obtained from its use. As more information is obtained regarding the risks and benefits of each herbicide, fewer herbicides are registered for aquatic use by the US Environmental Protection Agency (USEPA) (Bottrell 1979). This reduction in registrations is mainly a result of the removal of more toxic and persistent herbicides from use, the increased use of less persistent and less toxic herbicides, and the high cost of developing and registering new aquatic herbicides.

Federal Acts other than FIFRA and State regulations may also apply to herbicide selection for a particular situation. Acts related to safe drinking water, public health, and water pollution may be applicable. The regional USEPA offices are frequently a good source of information and guidance on the Federal laws and regulations. (See Appendix C for USEPA regional office addresses.) Many states use FIFRA regulations; however, State laws and permit requirements may be more restrictive than FIFRA.

At the Federal level, the use of herbicides in aquatic systems is regulated principally by FIFRA, as amended. The FIFRA is administered by the USEPA. Following is a summary of selected portions of FIFRA that may influence a user's decision regarding the use of a herbicide in a particular situation. If you are a frequent or large-volume user of pesticides, you may want to obtain a copy of FIFRA (Parts 162-180) to familiarize yourself with the details of this act. In the interim, the following summary may be of value:

<u>a</u>. All herbicides distributed, sold, or received by a person in any State must be registered with the USEPA. This requirement applies to herbicides produced and distributed solely within a State as well as to those moving in interstate commerce.

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* See References at the end of the main text.

b. It is a violation of Federal law to use a herbicide in a manner inconsistent with its label. The label will provide instructions on how to use the product correctly and will detail specific safety measures. Information on the container may not be the complete label. Make certain that all labeling information is obtained.

c. All herbicide uses must be classified as either "general" or "restricted." FIFRA requires the user to be certified to apply any herbicide classified for restricted use.

d. A herbicide or one or more of its uses may be classified for restricted use. This classification applies if it is determined that, when following label directions without additional regulatory restrictions, the herbicide has the potential to cause unreasonable adverse effects on the environment or injury to the applicator.

e. If a herbicide or one or more of its uses has been classified for restricted use, the herbicide must be applied by or under the direct supervision of a certified applicator. Restricted use herbicides may also have other restrictions; check the labels of restricted use herbicides for further information. Seasonal or regional limitations for use may apply, or there may be a requirement for monitoring residues after use.

f. Some herbicides may have split registration. Some uses of a split registration may be restricted, while other uses may be unrestricted.

g. FIFRA recognizes two classes of certified applicators:

   (1) Commercial applicator. A certified applicator (whether or not he is a private applicator with respect to some uses) who uses or supervises the use of any herbicide (with compensation) on any property not owned or rented by him or his employer. To apply restricted use herbicides in aquatic sites, commercial applicators must be certified in aquatic plant control.

   (2) Private applicator. A certified applicator who uses or supervises the use of any herbicide that is classified for restricted use on property owned or rented by him or his employer or (if applied without compensation) on the property of any other person. As a minimum requirement for certification, a private applicator must show that he possesses a practical knowledge of pest problems and pest control practices associated with his operations.

h. States may certify applicators of restricted use herbicides upon approval of a State plan by the USEPA. The State plan need not include an aquatic pest control category for commercial applicators. Standards of competency must conform and be at least equal to those prescribed by the USEPA. In addition, Federal employees may be further constrained by needing to satisfy State/local requirements.

i. Indian reservations not subject to State jurisdiction may submit plans for certifying applicators to the USEPA.

j. In the absence of other certification procedures, the USEPA may certify applicators at regional offices.

k. Herbicides may be used under Emergency Use Permits (EUPs) if:

(1) No herbicide is registered for the particular use, or no alternative methods of control are available to control a "pest outbreak."

(2) Significant economic or health problems will occur without the use of the pesticide.

(3) The time available is insufficient for a herbicide to be registered for the particular use.

l. Herbicides may be registered under EUPs to accumulate information needed for registration of a pesticide not registered or a registered pesticide for a new use. States may issue EUPs for persons accumulating information to support State registration of a herbicide to meet special local needs, or to any agricultural research agency or educational institution conducting work within the State.

m. A State may register a new herbicide or an additional use of any Federally registered herbicide for distribution and use within that State if:

(1) There is a special local need.

(2) Registration for the same use has not previously been denied, disapproved, suspended, or cancelled by the USEPA because of health or environmental concerns about an ingredient contained in the herbicide product.

(3) The registration is in accord with the purposes of the FIFRA.

n. A State may further require that a herbicide be registered under State law as well as under the FIFRA.

o. When using mixtures of herbicides (tank mixes), the user must adhere to the application procedures and precautions of the most restricted herbicide.

# APPENDIX C: ADDRESSES OF US ENVIRONMENTAL PROTECTION AGENCY NATIONAL AND REGIONAL OFFICES

# ADDRESSES OF USEPA OFFICES

USEPA Headquarters

Pesticide Program:
Office of Pesticide Program
Rm. E539
401 M St. SW
Washington, DC 20460
(202) 557-7460

Pesticide Registration:
Office of Pesticide Program
Registration Division
Rm. E347
401 M St. SW
Washington, DC 20460
(202) 557-7460

Pesticide Research and Monitoring:
Office of Pesticide Program
Hazard Evaluation Division
Rm. 821 CH-2
401 M St. SW
Washington, DC 20460
(202) 557-7351

Experimental Use Permits,
Special Local Need Registration:
(202) 755-4851

Emergency Exemptions:
(202) 426-0223

Pesticide Disposal:
(202) 755-8023

USEPA Regional Offices
(Pesticide Programs)

Region I:
John F. Kennedy Federal Building
Rm. 2203
Boston, MA 02203
(617) 223-0585
FTS: 223-0585

Region II:
Environmental Services Division
Woodbridge Ave.
Edison, NJ 08817
(201) 321-6765
FTS: 340-6765

Region III:
Curtis Building, 6th & Walnut Streets
Philadelphia, PA 19106
(215) 597-8175
FTS: 597-8175

Region IV:
345 Courtland St. NE
Atlanta, GA 30308
(404) 881-3222
FTS: 257-3222

Region V:
230 South Dearborn St.
Chicago, IL 60604
(312) 353-5220
FTS: 353-5220

Region VI:
1201 Elm St.
Interfirst-Two Building
Dallas, TX 75270
(214) 729-6674
FTS: 729-6674

Region VII:
726 Minnesota Ave.
Kansas City, KS 66101
(913) 236-2835
FTS: 757-2835

Region VIII:
One Denver Place
Suite 1300
999 18th St.
Denver, CO 80202
(303) 293-1730
FTS: 564-1744

Region IX:
215 Fremont St.
San Francisco, CA 94105
(415) 974-8366
FTS: 454-8366

Region X:
1200 6th Avenue
Seattle, WA 98101
(206) 442-1495
FTS: 399-1495

# APPENDIX D: SPECIAL LOCAL NEED AND EMERGENCY EXEMPTION PERMIT REQUESTS

# EXEMPTION PERMIT REQUESTS

Form Approved OMB Approval No xxxx-xxxx. Approval Expires xx-xx-xx

United States Environmental Protection Agency
Office of Pesticide Programs
Registration Division (TS-767)
Washington, DC 20460

EPA

# Application for/Notification of State Registration of a Pesticide To Meet a Special Local Need

*(Pursuant to Section 24(C) of the Federal Insecticide, Fungicide, and Rodenticide Act, as Amended)*

**For State Use Only**

Registration Number Assigned

Date Registration was Issued

Expiration Date

1. Name and Address of Applicant for Registration

2. Product Is: *(check one)*

| EPA-Registered ☐ | EPA Reg. No. |
|---|---|
| New *(not EPA-registered)* ☐ Attach EPA Form 8570-4, Confidential Statement of Formula for new products. | EPA Company No. |

3. Active Ingredient(s) in Product

4. Product Name

5. If this is a food/feed use, a tolerance or other residue clearance is required. Cite appropriate regulations in 40 CFR Part 180, 21 CFR Part 193, and/or 21 CFR Part 561.

6. Type of Registration: *(give details in Item 11 or on a separate page, properly identified and attached to this form)*
   - ☐ a. To permit use of a new product.
   - ☐ b. To amend EPA registrations for one or more of the following purposes:
     - ☐ (1) To permit use on additional crops or animals.
     - ☐ (2) To permit use at additional sites.
     - ☐ (3) To permit use against additional pests.
     - ☐ (4) To permit use of additional application techniques or equipment.
     - ☐ (5) To permit use at different application rates.
     - ☐ (6) Other *(specify)*

7. Nature of Special Local Need: *(check one)*
   - a. ☐ There is no pesticide product registered by EPA for such use.
   - b. ☐ There is no EPA-registered pesticide product which, under the conditions of use within the State, would be as safe and/or as efficacious for such use within the terms and conditions of EPA registration
   - c. ☐ An appropriate EPA-registered pesticide product is not available

8. If this registration is an amendment to an EPA-registered product, is it for a "changed use pattern" as defined in 40 CFR 162.152(c)?
   ☐ No ☐ Yes *(discuss in item 11 below)*

9. Has an EPA Registration or Experimental Use Permit for Use of This Chemical Ever Been: *(Check applicable box(es))*
   ☐ Sought ☐ Issued ☐ Denied ☐ Canceled ☐ Suspended
   Previous Permit Action: ☐ Registration ☐ Experimental Use Permit
   ☐ No Previous Permit Action

10. Has a FIFRA Section 24(C) Registration for This Use of the Product Ever, by Another State, Been: *(Check applicable box(es))*
   ☐ Sought ☐ Issued ☐ Denied ☐ Revoked
   If *Yes* to any of the above, list States in item 11 below.
   ☐ No FIFRA Section 24(C) Action

Signature of Applicant or Authorized Representative

Title

| Telephone Number | Date |
|---|---|

11. Comments

**Determination by State Agency**

This registration is for a Special Local Need and is being issued in accordance with section 24(c) of FIFRA, as amended. To the best of our knowledge, the information above is correct, except as noted in Comments below or in attachments.

| Name, Title, and Address of State Agency Official | Comments *(by State Agency Only)* | Received by EPA |
|---|---|---|
| Signature of State Agency Official | | |
| Tele[illegible]ne Number / Date | | |

EPA Form 8570-25 (5-86)

P-14
Rev. 2/82

U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDE PROGRAMS
REGISTRATION DIVISION (WH-567)
WASHINGTON, D. C. 20460

APPLICATION FOR/NOTIFICATION OF STATE REGISTRATION OF A PESTICIDE TO MEET A SPECIAL LOCAL NEED PURSUANT TO 40 CFR PART 162, SUBPART B AND SECTION 24 (C) OF THE FEDERAL INSECTICIDE FUNGICIDE, AND RODENTICIDE ACT, AS AMENDED

IMPORTANT: See reverse before completing/submitting this form.

**FOR EPA USE ONLY**

90th Day

[ ] Approved
[ ] Disapproved
Date ____________

Federal Register Notice

**FOR STATE USE ONLY**

Registration Number Assigned
WI-860001

Date Registration was Issued
March 21, 1986

Expiration Date
December 31, 1991

1. NAME AND ADDRESS OF APPLICANT FOR REGISTRATION
Chevron Chemcial Company
15049 San Pablo Ave
P O Box 4010
Richmond CA 94804-0010

2. PRODUCT IS: (check one)
[ ] NEW (not EPA-registered)
[X] EPA-REGISTERED (give number)
EPA REG. NO. 239-1663

3. EPA COMPANY NUMBER
239

4. EPA ESTABLISHMENT REGISTRATION NUMBER
239-CA-1

5. PRODUCT NAME
ORTHO Diquat Herbicide H/A

6. TYPE OF REGISTRATION: (give details in item 11 or on a separate page, properly identified and attached to this form)
[ ] a. To permit use of a new product.
[X] b. To amend EPA registrations for one or more of the following purposes:
[ ] (1) To permit use on additional crops or animals.
[X] (2) To permit use at additional sites.
[ ] (3) To permit use against additional pests.
[ ] (4) To permit use of additional application techniques or equipment.
[ ] (5) To permit use at different application rates.
[X] (6) To prescribe special label directions for one or both of the following purposes:
[X] (a) Preventing unreasonable adverse effects on man or the environment under local use conditions.
[ ] (b) Providing for local use conditions affecting pesticide efficacy.
[ ] c. To serve other purposes.

7. NATURE OF SPECIAL LOCAL NEED: (check one)
[ ] a. There is no pesticide product registered by EPA for such use.
[X] b. There is no EPA-registered pesticide product which, under the conditions of use within the State, would be as safe and/or as efficacious for such use within the terms and conditions of EPA registration.
[ ] c. An appropriate EPA-registered pesticide product is not available.

8. IF THIS IS A FOOD/FEED USE REQUIRING TOLERANCES OR OTHER RESIDUE CLEARANCES, CITE APPROPRIATE REGULATIONS IN 40 CFR 180, 21 CFR 123, AND/OR 21 CFR 561.
40 CFR 180.226

9. IS THIS REGISTRATION FOR A "CHANGED USE PATTERN" AS DEFINED IN 40 CFR 162.152(c)?
[X] NO [ ] YES

10. HAS AN EPA REGISTRATION OF, OR EXPERIMENTAL USE PERMIT FOR THE PRODUCT EVER BEEN SOUGHT, ISSUED, DENIED, CANCELED, OR SUSPENDED?
[ ] NO [X] YES

11. COMMENTS

12. HAS A REGISTRATION OF THE PRODUCT (UNDER SECTION 24(c)) EVER BEEN SOUGHT FROM, OR DENIED OR REVOKED BY, ANOTHER STATE?
[ ] NO [X] YES

SIGNATURE OF APPLICANT OR AUTHORIZED REPRESENTATIVE
Frank H. Plescia
Frank H. Plescia

TITLE
Regulatory Specialist-State Liaison

TELEPHONE
(415)231-6349

DATE
January 16, 1986

**DETERMINATION BY STATE AGENCY**

*This registration is related to a Special Local Need, as defined in 40 CFR 162.152(k), and is being issued in accordance with the approved State Plan and the Regulations at 40 CFR Part 162 Subpart B. To the best of our knowledge, the information above is correct, except as noted in COMMENTS below or in attachments.*

COMMENTS (BY STATE AGENCY ONLY)
SEE COMMENTS ON ATTACHED PAGE

RECEIVED BY EPA-OPP, REGISTRATION DIVISION, WASHINGTON, D. C. 20460

NAME AND TITLE OF STATE AGENCY OFFICIAL
EDWARD A BERGMAN, Ph.D Pesticide Spec

TELEPHONE NUMBER
608/266-0177

SIGNATURE OF STATE AGENCY OFFICIAL
Edward A. Bergman

DATE
3/21/86

Chevron Chemical Company

# ORTHO Product Bulletin

**SUPPLEMENTAL LABELING**
**ORTHO DIQUAT**
**HERBICIDE-H/A**
**EPA Reg. No. 239-1663**

For Distribution and Use Only in Wisconsin

It is a violation of Federal Law to use this product
in a manner inconsistent with its labeling.

## AQUATIC USE DIRECTIONS

For application to ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, streams, and rivers which are slow moving or quiescent, for control of Duckweed (Lemna spp.), Watermilfoil (Myriophyllum spp.) and Elodea (Elodea spp). When using this product under this Supplemental Labeling, do not apply it to control pests other than those previously named. All applications must be made in compliance with the following conditions and directions:

1. The person making the application shall be a certified applicator in the category Aquatic Pest Control and shall be licensed as a Commercial Applicator of Restricted-Use Pesticides, or shall be working under the direct supervision of a person with these qualifications.

2. The application must be authorized by a current valid aquatic nuisance control permit issued by the Wisconsin Department of Natural Resources (DNR) under Ch. NR107, Wis. Adm. Code, and the permit shall be in the physical possession of the user during the application.

3. Notification requirements beyond those required by NR 107.03 (3) and (4) for treatment of quiescent bodies of water: Written notice of the application shall be given at least 24 hours in advance of application to all persons who obtain their drinking water or water livestock or irrigate crops, from water in the area intended to be treated or within 100 yards of the area intended to be treated. Notice shall state the name, address, and phone number of the DNR permittee, the DNR permit number, the name of the herbicide to be used, the intended date of application, and shall warn that treated waters are not to be used for drinking, animal consumption, spraying, irrigation, or domestic purposes for 14 days after the application. The term "domestic purposes" includes drinking, bathing, cooking, and watering vegetation.

WISCONSIN DEPARTMENT OF AGRICULTURE, TRADE AND CONSUMER PROTECTION

REVIEW OF SPECIAL LOCAL NEED REGISTRATION APPLICATION AND PRELIMINARY ENVIRONMENTAL ASSESSMENT FOR CHEVRON CHEMICAL CO. DIQUAT HERBICIDE H/A

## I. NATURE AND PURPOSE OF PROPOSED ACTION

### A. Registration Authority

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (U.S.C. 136 et. seq.) is the national law governing pesticide sale and use. Under that law, pesticides must generally be registered by the U.S. Environmental Protection Agency under section 3 of the act before they may enter commerce in the United States. In writing the act, Congress realized that there may be situations in which pest control by use of pesticides is necessary, but that it would not be economically feasible for a prospective registrant to develop the data needed to get a national registration under sec. 3 if the pest control need existed only on a specialized or local basis. Therefore, sec. 24(c) of the act was created, which states, in part, that "A state may provide registration for additional uses of federally registered pesticides formulated for distribution and use within that State to meet special local needs in accord with the purposes of the Act and if registration for such use has not previously been denied, disapproved, or cancelled by the Administrator." The federal regulations (40 CFR 162.150-162.156) specify procedures to be followed by states in issuing such registrations, and by EPA in reviewing the work of the states. The EPA must be immediately notified of a state registration action under sec. 24(c); the agency has 90 days to review the action and disapprove it if necessary.

Section 94.69(11), Wis. Stats., authorizes the Department of Agriculture, Trade and Consumer Protection to adopt rules on registration of pesticides to meet special local needs as authorized by FIFRA and to impose fees to cover the cost of the registration. Section Ag 29.08, Wis. Adm. Code, states the procedures used by the Department in its special local need registration activities.

### B. Background

Herbicides containing the active ingredient diquat dibromide have been used to control aquatic weeds for over a decade.

In 1982 the Chevron Chemical Company, hereafter referred to as Chevron, revised their diquat label to comply with conditions established by EPA to assure compliance with tolerance guidelines. After reviewing Chevron's diquat label the Department informed the company that the wording in their label prohibited certain previous users from using diquat. As a result of the Department's label interpretation, Chevron applied, in June 1984, for a special local need registration. After the Department determined the local need for the pesticide and reviewed the environmental consequences of the action, it granted Chevron a special local need registration for the control of three aquatic weed pests. The registration was effective through December 31, 1985.

The Chevron Chemical Company has requested renewal of their special need registration for use of diquat in Wisconsin. The company has requested the renewal for the same label conditions that the Department approved in 1984.

This document presents a historical review of the factors that led up to Chevron's initial request for a special local need registration for use of diquat in Wisconsin and an assessment of the potential environmental consequences of the local need registration.

Under terms of the Federal Food, Drug, and Cosmetic Act (FFDCA), potable water is considered a processed food. Under that act, tolerances or exemptions from a tolerance must be established by rule for substances added to a processed food. The EPA considers that all surface waters are actually or potentially potable; therefore, addition of substances (such as pesticides) to such water must be covered by a food additive tolerance under the FFDCA regulations. On November 15, 1972, an "interim" tolerance of 0.01 parts per million (ppm) was set for residues of diquat herbicide in potable water. On February 24, 1982, the EPA published a rule setting a "final" tolerance for residues of diquat in potable water of 0.01 ppm. No numerical change in the tolerance was made in going from "interim" to "final", and the EPA's review of information during the tolerance-setting process did not disclose any new risks from this diquat use which would lead to a substantial change in the regulatory position regarding this use of the pesticide.

However, through the rulemaking process, the EPA did set certain conditions which are intended to assure compliance with the tolerance by preventing certain uses of the water for a period of time. In addition, the tolerance is effective only for certain intended uses of the pesticide; the tolerance is not intended to cover residues resulting from misuse of the pesticide. These conditions were implemented through changes in the federally-registered labels of diquat herbicides. Since, by law, pesticide users must comply with label directions and are prohibitied from using pesticides in a manner inconsistent with their labeling, changes in the label directions should implement the limiting conditions resulting from the rules setting the tolerances. These label changes were implemented promptly by the registrants of diquat.

Diquat Herbicide H/A (EPA Reg. No. 239-1663), produced by Chevron Chemical Co., Richmond CA, is a typical diquat aquatic herbicide. There are two sets of label directions for this product which implement the tolerance rule. The first reads: "For application only to ponds, lakes, and drainage ditches where there is little or no outflow of water and which are totally under the control of the product's user. Do not use the treated water for animal consumption, spraying, irrigation, or domestic purposes for 14 days after treatment". The second set of label directions, which is provided through supplemental labeling, reads: "For application to ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, streams, and rivers which are slowmoving or quiescent only by the Corps of Engineers or other Federal or State Public Agencies, or contractors or licensees under their direct control. Do not use the treated water for animal consumption, spraying, irrigation, or domestic purposes for 14 days after treatment, or until such time as an approved assay (example: PAM II Spectrometric Method) shows that the water does not contain more than 0.01 part per million of diquat dibromide (calculated as the cation). No applications are to be made in areas where commercial fish processing, resulting in the production of fish protein concentrate or fish meal, is practiced. Before application, coordination and approval of local and/or state authorities must be obtained."

As a result of the new labeling, there are two groups of people who are allowed to use diquat for aquatic pest control: 1) persons who have total control over a pond, lake, or drainage ditch which has little or no outflow of water; and 2) state or federal agencies, or contractors acting on their behalf, who may treat certain types of slow-moving or quiescent water. Certain persons or groups who could use diquat under the old labeling are now prevented from doing so because they do not fall into either of the two allowed categories of users. Prominent examples of such persons or groups would include any governmental body more local than a "state", and persons other than a state or federal agency or contractor thereof who desire to treat a body of water which they do not wholly control. As a specific example, the Madison-area lakes on the Yahara River chain could only be treated by a state or federal agency or contractor thereof; private landowners or lakeshore property associations could not make such treatments since they do not have control over use of the water, and they are not state or federal agencies or licensees or contractors thereof for purposes of aquatic pest control.

The purpose of the tolerance rules, and the label wording implementing them, is quite clear. First, 14 days must generally be allowed before using the water for certain purposes, in order for residues to decline to the point to which they do not present a significant addition of diquat residues to the human food chain. The exception is state or federal agencies (etc.), which may have the chemical analytical capability to determine that residues have declined to 0.01 ppm or less in less than 14 days; it is assumed that private parties would not have this analytical capability. Second, private parties must have control over the body of water to be treated, in order to prevent persons who may be unaware of the treatment from using the water and thereby becoming exposed to diquat residues or allowing residues to enter the human food chain. Third, the waters must have little or no outflow, in order to prevent treated water from moving to points where persons unaware of the treatment would attempt to use the water for some purpose. Fourth, state or federal agencies (etc.) are allowed to treat a greater number of types of bodies of water, and that water may have some outflow, because it is assumed that such treatments are done for some public good and that such agencies can take steps to inform the public of the treatment.

After receiving new diquat product labels, the Department reviewed them to determine under what conditions the product could be lawfully used. The Department's conclusions were forwarded to the Wisconsin Department of Natural Resources (DNR), which is charged with protection of the waters of the state and which administers a permit program regulating aquatic nuisance control. The DNR then issued a press release stating the new limitations on diquat use. The Department's conclusions were also made known to Chevron Chemical Co., which subsequently applied for the special local need pesticide registration in 1984 and reregistration in December 1985.

C. The Application for Registration

On May 11, 1984, the Department received an application for special local need registration from Chevron Chemical Co., 940 Hensley St., Richmond CA 94804. The application was for registration of the firm's product "Ortho Diquat Herbicide H/A", EPA Reg. No. 239-1663. The application was for registration of the product to control duckweed (Lemna spp.), watermilfoil (Myriophyllum spp.), Elodea (Elodea spp.), and other weeds listed on the federally-registered label, on ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, streams, and rivers which are slow moving or quiescent. Applications were proposed to be made in compliance with a number of conditions intended to prevent movement of diquat residues from treated waters into the human food chain. A copy of the proposed label submitted by Chevron is attached.

The application for registration was unusual in certain respects. Special local need registrations are usually issued for the purpose of authorizing pesticide uses in addition to those which are federally-registered, such as use on additional crops, animals, or sites, or to permit use against additional pests. Other usual SLN registrations may authorize use of additional application techniques, different application rates, or provide special use directions for the purpose of preventing unreasonable adverse effects on man or the environment under local conditions of use. However, the purposes for which a state may issue a SLN registration are not limited to those stated above. The diquat product already has a federal registration for all the types of bodies of water cited on the proposed SLN labeling, if such applicatons are made by state or federal agencies or licensees or contractors thereof. The federally-registered label lists all weed species cited on the proposed SLN labeling. The application rates and techniques specified on the federally-registered label remained the same under the SLN registration. The difference between the present federal registration and the initial SLN registration, and therefore the effect of the SLN registration was to allow a new class of product users to apply the product for the same uses now allowed only for state and federal agencies (etc.), under certain conditions intended to prevent or limit resulting diquat residues in the human food chain. In other words, persons other than state or federal agencies (etc.) would be allowed to use the product in the same way that such agencies can now, if certain conditions are complied with. It must be noted that this group is not specifically prohibited from using the product by the federal label, but is effectively prohibited from use by interpretation of the terms used on the label.

D. The Application for Reregistration

On December 16, 1985 the Chevron Chemical Company requested a renewal of their special local need registration for use of diquat in Wisconsin. The proposed SLN label, if approved, would be the same as the label approved by the Department in 1984.

II. ISSUES FOR CONSIDERATION

The purpose of this section is to delineate, in general terms, the issues which will be considered in this review/assessment, within the context of the contemplated action, and to some extent, to state certain items which will not be considered and the reasons for that decision.

A. Existence of a Special Local Need

A state has authority to register a pesticide or use under FIFRA sec. 24(c) only if a special local need exists. In Wisconsin, a determination as to the existence of a special local need is the first step in the review process, since if that need does not exist, there is no authority to register and there is no point to further review of a registration application. In the context of this registration application, four questions must be answered: 1) is there a need to extend the user groups allowed to use diquat for all of the weeds mentioned on the federally-registered label and for all of the types of bodies of water requested?; 2) is there a need to extend the user groups allowed to use diquat for the three weeds specifically mentioned on the proposed labeling for all of the types of bodies of water requested?; 3) would alternative registered pesticides serve the needs of the additional user groups?; and 4) can persons already allowed to use diquat under the existing federal registration provide adequate control of the weeds of concern here?

B. Product Efficacy

Product efficacy is normally a major part of review of a SLN registration application for two reasons: 1) Wisconsin's view of the purpose of a SLN registration is that it must meet a special local need for pest control, i.e., the product must work as intended; 2) as a matter of consumer protection, the Department would require product efficacy before authorizing such use. As noted above, the actual effect of this SLN registration, if issued, would be to allow an additional group of people to use the product, under certain conditions. The efficacy review therefore becomes a matter of determining whether an additional group of applicators can use the product in an efficacious manner, under the proposed conditions.

C. Potential Effects on Humans and the Environment

As noted above, the product is already registered under FIFRA sec. 3 for use on all the types of bodies of water, against all of the pests, and using the same application methods which are proposed for the SLN registration. Presumably, the EPA, as required under the sec. 3 registration procedures, has made a finding that the available data show that such use will not lead to unreasonable adverse effects on man or the environment. The Department is required to make the same finding for any of its registration actions under FIFRA sec. 24(c). The registration, if issued, would have the direct effect of adding a new group of users of the product, thereby potentially increasing the amount of product use in aquatic settings (with possible subsequent effects) and exposing additional applicators to contact with the product. The consideration of potential effects on humans and the environment will generally be in that context.

D. Social and Economic Effects

The social and economic effects of the contemplated action will be discussed to the extent that they can be predicted.

E. Alternatives to the Action Under Consideration

The contemplated action is a pesticide registration. Within that context, the Department must consider whether a special local need exists (including alternative registered pesticides), whether the registration would lead to unreasonable adverse effects, and whether the proposed registration would indeed meet a special local need for pest control. On these grounds, the Department may issue the registration as requested, may flatly deny the registration application, or may suggest to the applicant that the registration application be modified so that it can be issued. The decision to use a specific pesticide at a particular site is open to public review under the Aquatic

Nuisance Control Permit Program (NR 107) administered by the Department of Natural Resources. Special local need registration allows a state to register a pesticide to control a local pest, but this registration does not mandate the use of chemical treatment or preclude the use of alternative weed control measures. The discussion of alternatives will be limited to the three options described in this paragraph, after this review/assessment has stated the consideration of the other factors necessary to intelligently consider the alternatives.

F. Potentially Controversial Issues

Three potentially controversial issues present themselves at this time. The first results from the application of a pesticide to bodies of water, per se; in the context of the contemplated action, the actual issue is introduction of additional increments of diquat to water by an additional group of users, since diquat may already be introduced to water by existing groups of authorized users. The second potentially controversial issue arises from the fact that ethylene dibromide (EDB) is used in the manufacture of diquat, and is present in the finished product in trace amounts. The findings of risk for EDB, and the past public concerns about EDB residues in the food supply, make the presence of EDB in diquat for aquatic application a potentially controversial issue. (This will also be considered in the section on potential effects on the human environment.) The third issue arises from the possibility that the registration application may be denied. The Department has received numerous inquiries on the status of diquat for aquatic weed control from persons who would like to use it, or have it used, on bodies of water which they use for various purposes. It appears from this situation that denial of the application would also be a controversial issue.

III. SPECIAL LOCAL NEED DETERMINATION

A. Nature, Extent, and Significance of the Pests

The three pests of concern are two submersed rooted weeds, watermilfoil (Myriophyllum spp.), and Elodea (Elodea spp.), and a floating weed, duckweed (Lemna spp.). They are considered to be potential aquatic nuisances in several of the northern states.

Watermilfoil reproduces prodigously, mainly vegetatively, but also by seed. Vegetative reproduction occurs when a portion of an existing plant is broken off by physical means, develops a root system, and begins life as a new plant. Vegetative reproduction is considered the primary means of propagation of tha plant. Floating masses of vegetative parts can accumulate in one portion of a body of water if driven by wind and wave action. These floating masses, in addition to the rooted plants, can interfere with navigation, fishing, and swimmming. The actual extent of occurrance of watermilfoil, and the extent of waters considered to have infestation levels serious enough to warrant control, have not been provided to the Department, although Dane and Waukesha Counties are considered to be areas with especially problematic infestations.

Elodea, like watermilfoil, is a rooted submersed aquatic weed. It is also found in several northern states. It is also similar to watermilfoil in that it can interfere with navigation, fishing, and swimming. The actual extent of Elodea infestation and the extent of waters considered to have an infestation level great enough to warrant control have not been provided to the Department.

Duckweed, unlike the two weeds previously discussed, is a floating weed. It has roots, but these do not attach to the bottom of the body of water. These plants reproduce primarily by vegetative means. They are easily windblown on the surface, and will accumulate on the downwind shoreline or where trapped by obstacles such as other weeds. A layer of plants one to two inches thick may accumulate on the surface, which can severely interfere with recreational use of the water and decrease its aesthetics. Nuisance levels of duckweed have occurred on Mirror Lake and Lake Delton (Sauk County) and Onalaska Lake (La Crosse County). Information on infestation in other lakes has not been provided to the Department.

The proposed labeling refers to the weeds mentioned on the federally-registered product label. These weeds are:

- Submersed weeds: Bladderwort, Coontail, Elodea, Naiad, Pondweeds, and Watermilfoil;
- Floating weeds: Pennywort, Salvinia, Water hyacinth, Duckweed, and Water lettuce;
- Marginal weeds: Cattails;
- Algae: Spirogyra and Pithophora.

With the exception of the information described above, no information has been submitted on the nature, extent, and significance of these weeds.

B. Is there a local need to use diquat to control all of the weeds mentioned on the federally-registered label?

Specific information has been provided to the Department, by the DNR and by potential users, on the three main weeds of concern. Although inquiries from interested potential users have been received, no information has been provided on the other weeds listed on the federal label. Therefore, the Department has not been able to establish the existence of a special local need for control of these other weeds.

C. Is there a need to control the three main weeds of concern?

Information provided to the Department verbally and in writing by the DNR and by lakeshore owners and lakeshore property owners associations, and in published literature, shows that each of the three main weeds of concern, as well as combinations of them, may create a nuisance on at least a few lakes in Wisconsin. The particular nuisance, as stated above, consists of interference with navigation and recreational use, and decreased aesthetic value. A secondary effect of this, particularly important in tourism areas such as Mirror Lake and Lake Delton, is that the nuisance created may very well hurt the tourist industry in such areas. The Department concludes that there is a need to control these three weeds by some means.

D. Alternative Pesticides

A search was made of EPA registration information to discover what other pesticides are registered on each of the proposed sites of use (lakes, canals, etc.) to control each of the three main weeds of concern. The result of the search is reported in Table 1.

Information used by the DNR and in the University of Wisconsin Extension's aquatic pest control training manual shows what the Wisconsin experience has been with use of three pesticides, including diquat, for control of each of the three weeds of concern here. This information is presented in Table 2.

The information in Tables 1 and 2, when combined, shows the site/pest combinations for which there are no feasible alternative pesticides to diquat. These results are shown in Table 3. Table 4 shows which pesticides may be feasible alternatives to diquat in a given site/pest situation, but for which no information is on hand to compare with diquat.

The conclusion reached after review of this information is that there are generally no effective alternative pesticides to diquat for the three weeds on the proposed types of bodies of water. In the one case where a significant alternative does exist (simazine for use on ponds to control duckweed and watermilfoil), control of those weeds can be accomplished in 1-5 weeks and 4-6 weeks after application, respectively, which does not provide the rapid kill shown by diquat and which is often considered a necessary part of an aquatic weed control program; this product is not registered for use on ponds to control the other weed of concern, Elodea. In addition, while there are effective registered alternatives for some specific sites (primarily 2,4-D to control watermilfoil on certain sites), and while a registered label could be devised which prohibits that use of diquat because an alternative does exist, such a label would most likely be incomprehensible to the user and quite possibly unenforcable. Similarly, such a label could also be written to prevent diquat use on specialized site/pest combinations for which no information was presented to compare diquat and the registered alternatives (such as some of the dichlobenil uses), but such a label would again be incomprehensible to the user and possibly unenforceable. The conclusion stated above is therefore derived from both the search for alternatives, as well as a determination on the practicality of limiting diquat use in those narrow cases where alternatives exist; generally, alternatives do not exist.

C. Alternative Users of Diquat

If there is a need to control the three weeds in the aquatic sites discussed above by use of diquat, can the persons already authorized to use diquat meet that need? There is no state program for control of nuisance aquatic weeds. Federal programs are limited to waters where there is substantial federal involvement, and do not include the heavily-infested lakes cited above, nor do they include most Wisconsin waters. Private parties are now limited to treating only a few types of waters, and those waters must be entirely under their control. Therefore, most Wisconsin waters (indluding those cited above as infested) cannot be treated with diquat under the federally-registered labeling.

D. Conclusion

In conclusion, there does appear to be a special local need for control of watermilfoil, duckweed, and Elodea in the types of bodies of water proposed to the Department, and a concurrent need to expand the types of groups allowed to carry out such treatment to actually control the pests. There is not sufficient information submitted to the Department to make such a determination for all of the weeds listed on the federally-authorized labeling, other than the three specificlly mentioned.

III. PRODUCT EFFICACY

A. Efficacy in General

Diquat is already known to be efficacious against the three weeds under Wisconsin conditions (see Table 2). Chevron submitted 11 studies of product efficacy as part of its application to the Department. In summary, these studies show the product to be efficacious on all three weeds at the proposed rates of application; in addition, the data show that the product is efficacious on watermilfoil and duckweed at rates less than that on the proposed labeling (0.5-1.0 ppm and 0.12-1.0 ppm, respectively). However, use at less-than-labeled rate against these two weeds does not have the probablility of success shown by use at the full rate.

B. Efficacy of Applications to be Made by an Additional Group of Users

The only remaining question as to whether the product could meet the special local need for pest control delineated above is whether the additional group of users could actually apply the product in an efficacious manner. Chevron has proposed that this use of the product be classified for use by applicators who are certified and licensed in the category Aquatic Pest Control, or who are working under the direct supervision of persons meeting those requirements. This is expected to have the effect of restricting the use to the more-highly skilled applicators, thereby providing greater assurance of proper product use and avoidance of adverse side effects. In addition, one must recall that prior to the introduction of the new federally-registered diquat labeling, the product could be used by anyone for the purposes described here. The product was used in this manner in Wisconsin in prior years. The Wisconsin experience has been that the product prior to the federal label change in 1982 and during the initial SLN registration was used in an efficacious manner.

## IV. POTENTIAL EFFECTS ON HUMANS AND THE ENVIRONMENT INCLUDING IMMEDIATE, LONG TERM AND CUMULATIVE EFFECTS

### A. General Fate of Diquat in the Aquatic Environment

Diquat is highly soluble in water. Therefore, after being applied to the surface of a body of water, the chemical spreads evenly throughout the treated area. Within a few days of application, most of the applied diquat is adsorbed onto surfaces of aquatic plants, onto suspended clay particles in the water, or into the bottom sediment. Diquat rapidly kills susceptible species of plants. The plants do not metabolize diquat, so that the chemical is present in and on the plants in an unaltered form at the time of plant death. As the dead plants sink to the bottom, microorganisms begin to decompose them. It has been shown that some of the diquat present in or on those plants can be metabolized by microorganisms, causing the release of water-soluble diquat degradation products. Those degradaton products have not been identified, but it has been shown that the entire diquat molecule is subject to such attack. Diquat which is not degraded in this manner is adsorbed onto bottom sediments. Diquat has a great affinity for three-layered clay minerals, and can become electrostatically locked into the clay mineral structure. Laboratory analysis of such soils or sediments includes as a first step the boiling of the sample in strong sulfuric acid, which actually destroys the clay particles and releases the diquat. Diquat is retained intact when sorbed onto soil particles and is not biologically available. Therefore, of a dose of applied diquat, a small protion will be degraded after the death of susceptible weeds, and most of the rest will be sorbed onto bottom sediments soon after application or during decomposition of dead weeds. Some of the applied diquat may be taken up by aquatic fauna while it is still dissolved in water and available shortly after aplication, and some may be taken up by aquatic fauna feeding on plants in the treated area or on the bottom of the treated area.

Numerous studies have been made of the persistence of diquat in the aquatic environment after application. An applied initial dose of 1 ppm in a reservoir declined to approximately 9 parts per billion (ppb) by 12 days after application; this reservoir was turbid with suspended clay at application. Another study found no detectable free diquat in a treated body of water four days after application. In a series of tests on a lake, it was found that diquat applied at 1 ppm to the surface decreased to 0.01 ppm or less in times varying from 1 to 15 days. Samples were also taken outside of the treated area; the maximum residue observed outside of the treated area was 0.1 ppm diquat four days after treatment at a distance of 100 feet. All other samples had 0.01 ppm or less diquat detected four days after treatment. Diquat was applied to 14 ponds to give initial concentrations in the water of 0.4 to 2.5 ppm; in 11 of the ponds, water residues decreased to 0.01 ppm or less in 4 to 16 days. The other 3 ponds were not sampled frequently enough to determine a residue decay rate. Similar results have been obtained in tests on other types of bodies of water.

The active ingredient, diquat dibromide, is currently being re-examined under EPA's registration standards program. The registration standards document will outline conditions for reregistration of pesticide products containing diquat dibromide. According to EPA, registrations standards document should be available sometime in 1986.

It is highly unlikely that there would be additional special local needs situations in Wisconsin that would require the Department to repeatedly register additional uses for other aquatic herbicides. Because repeated registrations for other aquatic herbicides is unlikely, generation of additional impacts attributed to repeated registrations of aquatic herbicides is also unlikely.

B. Applicators

The persons with the greatest risk of exposure to diquat from the proposed aquatic use will be those who mix, handle, and apply the concentrated chemical (as sold). Diquat is a moderately toxic pesticide through oral exposure, with an LD50 in rats of 230 mg/kg. The greatest risk of exposure is through dermal exposure. Toxic amounts of diquat will not penetrate unbroken skin, but the chemical can be an irritant to the skin and eyes. Spillage on cut or scraped skin poses a risk of the chemical entering the body. Oral, skin, and eye exposure may be largely avoided by adhering to the existing label directions requiring use of a face shield, rubber apron, and rubber gloves while handling the concentrate. Inhalation exposure is not a factor due to the low vapor pressure of diquat.

C. Persons Exposed to Aquatic Residues

In addition to applicators who may be exposed to the chemical while using it, one must consider persons who may use treated waters for swimming, waterskiing, or other recreational uses and receive direct exposure to treated waters. The diquat uses proposed for registration would generally result in initial concentrations of 1-2 ppm diquat cation in treated waters. As noted above, these levels decline sharply within several days of application. Chronic (lifetime or near-lifetime) exposure is not possible due to the limited nature of aquatic applications. Therefore, only the possibility of acute exposure must be considered. Many swimmers occasionally swallow some water. Chevron has estimated that a 150 pound adult would have to swallow approximately 3900 gallons of water containing 1 ppm diquat to achieve an equivalent dose to the rat oral LD50. As noted above, unbroken skin is not easily penetrated even by the concentrate; a dilute 1 ppm solution would seem to present a lower level of dermal hazard. No quantified information is on hand regarding the possibility of whether a 1 ppm solution presents a risk of eye irritation. It would seem that the proposed use presents little if any risk to humans exposed to treated waters through recreation. The EPA apparently came to the same conclusion when it authorized removal of a 14 day swimming restriction for treated waters from the diquat label.

D. Persons Consuming Fish from Treated Waters

Several studies have beeen done of uptake of diquat by fish living in treated waters. After application of a 1 ppm dose to a La Crosse area lake, bluegills were found to contain 0.09 ppm diquat (it should be noted that bluegills apparently have a tendency to retain small amounts of bottom sediments within their bodies). In a study with channel catfish, a bottom-feeding species, 1 ppm diquat was applied at 3-month intervals. Two months after the second treatment, no diquat was detected in fish harvested at that time; 5 months after the last treatment, no diquat was detected. This study also showed that the fish did not actively bio-accumulate diquat in their bodies. The major portion of diquat found in fish has been in the portions not eaten by humans. However, certain businesses which process fish into concentrate or meal do use the entire fish; therefore, the current federal diquat label bears a precaution against treating waters where fish are taken for such purposes. If issued, the SLN registration should also contain that condition.

E. Aquatic Fauna and Flora

Numerous species of aquatic plants are susceptible to the herbicidal effects of diquat, and it would be expected that most such plants within a treated area of a body of water would be killed. There are also non-susceptible species which would not be affected. It is not likely that diquat residues would reach high enough levels at a distance of more than 100 feet from a treated area to have any effect on plant life. It is possible that endangered or threatened plant species may be located in or near areas to be treated. The DNR aquatic nuisance control permit program is intended, in part, to prevent applications from being made in areas where such species are present. If this registration is issued, its terms should include a label precaution against making applications in such areas.

Direct toxicity of diquat to aquatic fauna is not likely for most species. Table 5 shows the acute and chronic toxicity of diquat to a number of species of aquatic fauna, including both fish and insect larvae. The only species of fish which would appear to be threatened by the initial applied level of 1 ppm diquat is newly-hatched striped bass.

Diquat use may pose an indirect threat of fish toxicity through killing plants. As such plants decompose, the dissolved oxygen content of the water may decrease to a point at which fish may not obtain enough oxygen. For this reason, it has been customary to treat only a small portion of a body of water at one time, thereby preventing an overall lowering of dissolved oxygen content.

Another indirect potential effect of diquat use would be removal of habitat of snails or insect larvae which live in or on aquatic weeds. While this would occur only on a small scale, it would be an unavoidable effect of the proposed use.

The last potential effect of the proposed use is also an indirect one. As affected vegetation dies, plant cell contents are released into the water. These contents may include significant amounts of plant nutrients, particularly phosphorus. In turn, this may provide enough fertilizer in the water to promote an algae bloom. Mechanical harvest of weeds after treatment would alleviate some of this effect; however, the Department does not have the capability of requiring this step as a condition of registration.

F. Ethylene Dibromide in Diquat

The main ingredient in formulated diquat herbicides is diquat dibromide, although it is only the diquat cation which is herbicidally active. Ethylene dibromide (EDB) is used as a chemical intermediate in production of diquat dibromide, from which diquat herbicides are produced. As a result of this, levels of EDB are present as a contaminant in finished diquat herbicide products, including the one contemplated for registration. Current analysis of Chevron's formulated diquat herbicide shows that it contains not more than 30 ppm EDB. Recent communications from the actual manufacturer of diquat dibromide have stated that the EDB contamination level in the concentrate has been reduced to a maximum of 10 ppm.

EDB is a pesticide (fumigant) by itself and has a number of non-pesticidal uses such as an anti-knock additive in gasoline. An EPA review of the risks and benefits of pesticidal uses of EDB concluded that the substance was a potent carcinogen and that risks outweighed the benefits of most of its pesticidal uses. Those uses have been, for the most part, cancelled. In addition, the finding that widespread fumigant use of EDB had led to its presence in many items in the American food supply led to the establishment of recommended maximum levels of EDB in various groups of food commodities. These levels are 30 ppb in ready-to-eat foods, 150 ppb in foods requiring cooking before consumption, and 900 ppb in raw grains. Some states elected to use the minimum detectable level of 0.1 ppb (100 parts per trillion) as the maximum level in food commodities.

Persons may be exposed to EDB in diquat by two routes: exposure to the concentrate or spray solution during application, and exposure to residues in treated waters. Chevron has calculated that application of diquat to water at the maximum labeled rate (with EDB present in the product at 30 ppm) would result in an EDB concentration in the water of 57 parts per trillion (0.057 ppb). This is almost 1000 times less than the level allowed in most states for residues in ready-to-eat foods which are consumed daily, and is a little more than half of the level used in those states using the minimum detectable level as a food standard. It does not appear that EDB in diquat presents a significant risk to persons using or consuming treated waters. Chevron has also calculated that persons handling diquat product would be exposed to EDB levels in excess of OSHA standards only in the most extreme conditions, i.e. a spill of the concentrate in a confined unventilated space. Using 10 ppm, now found as the maximum contamination level, the concentrations are reduced at least 3-fold.

V. PERSONS AFFECTED; ECONOMIC AND SOCIAL EFFECTS

A. Sellers and Applicators of Diquat

Persons engaged in commerce involving diquat would derive economic benefit from any additional allowed uses of the product, since such conditions would slightly increase the amount sold and used. The increase in sales would be of minute economic benefit to Chevron Chemical Co., somewhat larger benefit to individual sellers of diquat, and greatest benefit to the relatively few certified commercial applicators engaged in aquatic pest control in Wisconsin. No social effects (other than economic benefits) are expected for these persons.

B. Persons Using Treated Waters for Recreation

The proposed registration, if issued, would be of social benefit to recreational users of treated waters in at least one respect. Given that one of the main needs for aquatic weed control is to maintain the capability of surface waters to support recreational use and navigation, persons engaged in such activities would directly benefit from the registration. They may also find that their uses of surface waters would be curtailed if the registration is not granted.

There is also a negative aspect to this, due to the general concern about pesticide use in our society. Treatment of water may raise concerns about the safety of its use. The actual risks involved in such use have been discussed above. Persons using state waters for recreational use have been generally supportive of actions taken to maintain that use, including weed control.

Persons who fish in treated waters are a group which may be particularly concerned about the proposed use of diquat. As related above in the discussion of environmental effects, only the early growth stage of the striped bass appear susceptible to diquat toxicity at the rates proposed for application. The proposed registration would not generally result directly in reduction of fish populations through toxicity, and if applications to a given body of water are confined to a limited area, reduction of oxygen by decomposition of treated weeds should not be significant enough to lead to fish kills. Significant residues in edible portions of fish taken from treated areas are not expected to occur, based on available data.

There are certain risks which would result if this registration is granted, and these have been discussed above. The existence of this document would provide a basis for answering questions from recreational users as to the safety of treated waters, and provides a framework for weighing the risks and benefits of aquatic use of diquat. This should alleviate some of the general concerns that may arise about this pesticide use.

In addition, the proposed registration would include certain notice and posting provisions which exceed the precautions required under the federally registered labeling and NR 107. This is a further precaution to prevent unknowing contact with treated waters.

C. Persons Using Treated Waters for Economic Purposes

This group consists primarily of persons involved in the tourist industry who rely on recreational use of water (boating, swimming, and fishing) to draw customers. Persons who operate such businesses on lakes where heavy weed infestations exist would benefit from the registration, if issued, and there appears to be support from this group for the registration.

Commercial fishermen and guides would also be included in this group. The same factors related above for recreational users of treated waters would also apply to this group.

D. Government

The proposed registration, if issued, would have a direct effect of increasing the number of aquatic nuisance control permits to be handled by the DNR, and increasing the amount of supervision of aquatic pesticide use carried out by that agency. This would be expected to raise that agency's expenditures somewhat, but the expected number of permits is small, so the increase would not be significant. The DNR has not taken an official position of either support or opposition to the registration.

VI. ALTERNATIVES TO THE CONTEMPLATED ACTION

A. Legally Available Alternatives

The available alternatives are limited by the nature of the contemplated action. The Department's alternatives are confined to pesticide registration decisions. The available decisions are: issuance as requested; denial; and issuance under terms or conditions different than those requested, if the applicant agrees to such (if the applicant does not, the Department would deny the application).

B. Deny Application for Registration

As stated above, the Department has found that a special local need exists for control of three aquatic weed species, but not for all of the weeds now listed on the federally-registered labeling. The Department has also found that authorizing an additional group of product users would meet that special local need. The information in this assessment leads to a conclusion that the benefits of diquat use to control the three weed species would exceed the risks involved, and that therefore a registration for these limited purposes could be issued. The Department concluded that it could not, based on existing information, issue the registration initially requested by Chevron in 1984, which included all weed species listed on the federally-authorized label, and the application for registration on that basis was revised to include only the three weed pests for which registration was ultimately approved. Denial of the special local need proposal would limit the use of diquat to the conditions on the existing national label.

C. Issue Registration with Terms Different than those Proposed by the Applicant

Legally, an application for registration can be denied, and the applicant can re-apply for registration, seeking authorization under more limited terms and conditions than in the initial application. As a practical matter, to save time and expense, a simpler procedure, based on agency review and/or public concern, may be used, in which the Department informs the applicant that the initial registration cannot be issued, and informs the applicant of the terms and conditions under which a registration could be acceptable. If the applicant finds those terms and conditions acceptable, such a limited registration can be issued. Given that the initial application for registration could not be issued, but that a special local need existed which could be met by a more restricted use of diquat than proposed, the Department pursued a more restrictive alternative with the applicant. This alternative was ultimately approved by the Department in 1984 and Cheveron has requested renewal of their application based on the alternative selected.

## VII. POTENTIALLY CONTROVERSIAL ISSUES

### A. Issuance of a Registration Allowing Aquatic Pesticide Use

As noted above under "Social and Economic Effects", chemical treatment of water will raise concerns among some persons. The fact that such use has some risks will add to those concerns. The development of this document, and the availability of literature on the pest situation and on diquat, may alleviate these concerns somewhat, at least to the extent that the risks and benefits of the proposed registration have been evaluated and that information is available. The Department's legal and social obligation is to consider relative risks and expected impacts to determine whether this proposal is a major action which would significantly affect the quality of the human environment.

### B. Failure to Control Pests if the Registration Application is Denied

The economic and social benefits of issuance of the registration have been noted above; these are of most significance to a few pesticide applicators, and potentially to many recreational users of water and the tourism industry. Non-issuance of the registration would lead to economic and social loss to these groups, which in turn would generate controversy.

### C. Ethylene Dibromide

EDB is present at low levels in diquat, and would consequently be added to waters treated with diquat. EDB is a potent carcinogen, and has been the subject of great public concern during the six months prior to the writing of this document. The Department is quite familiar with the public concerns over EDB, since the Department was responsible for enforcing the prohibitions on EDB pesticide use, carried out sampling and analysis of food commodities for EDB residues, and removed excessively-contaminated foods from the market. It is certainly valid to inquire what risks may result from the addition of EDB to waters of the state through diquat use. The Department's evaluation of such risks is that they are low, due to the exceedingly low concentration of EDB in water that would result from treatment, and that the relative risks are much lower than those presented by contamination of the food supply and by exposure through gasoline and non-pesticidal industrial uses of EDB.

## VII. CONCLUSION

The Department concluded in 1984 that it could not issue the registration as requested by Chevron Chemical Co. because a special local need for control of all of the weed species requested was not been shown to exist.

Ultimately the Department concluded that it could grant a more limited registration, authorizing distribution of Diquat

Herbicide H/A label in Wisconsin with use directions for controlling watermilfoil, duckweed, and Elodea in ponds, lakes, canals, bayous, reservoirs, streams, drainage ditches, marshes, and rivers, according to the application directions specified on the federally-authorized supplemental label. This registration would meet a special local need for pest control without causing unreasonable adverse effects on man or the environment if certain conditions were adhered to. These conditions included compliance with label directions, use only by or under the direct supervision of applicators who are certified and licensed in the category Aquatic Pest Control, prior authorization of the application under an Aquatic Nuisance Control permit issued under Ch. NR107, Wis. Adm. Code, and certain notification and posting steps to warn against making certain uses of treated waters for 14 days after treatment or until chemical analysis shows that diquat residues in the treated waters have declined to 0.01 ppm or less.

As a result of this analysis the Department has made a preliminary determination that this proposal is not a major action which would significantly affect the human environment.

Date 3/7/86 By Edward A. Bergman
Signature of Evaluator

The decision indicating that this document is in compliance with s. 1.11, Stats., is not final until certified by the Administrator of the Agricultural Management Division or designee.

Date ______________ By ______________________
Signature of Administrator
or Designee

KPR:JPE/EAB 3-86

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

RECEIVED

17 MAY 1985

MAY 28 1985

REPLY TO
ATTENTION OF:

DAEN-CWO-R

Registration Division (TS-767)

Mr. Douglas Campt
Registration Division (TS-766C)
Environmental Protection Agency
401 M Street, Southwest
Washington, DC 20460

RECEIVED 5/28/85

Dear Mr. Campt:

The enclosed application is submitted in compliance with 40 CFR Part 166 and Section 18 of the Federal Insecticide Fungicide and Rodenticide Act (FIFRA), as amended by the Federal Environmental Pesticide Control Act of 1972 for emergency exemption from certain provisions of the Act.

We request approval of the Seattle District plans to treat Eurasian watermilfoil with the aquatic herbicide 2,4-D in Osoyoos Lake, Okanogan County, Washington and the Pend Oreille River, Pend Oreille County, Washington.

We are aware of your agency's concerns over the use of emergency exemptions to circumvent the registration process. The situation for the use of 2,4-D against Eurasian watermilfoil, however, is entirely different. The Corps Waterways Experiment Station and the U.S. Bureau of Reclamation have done extensive field work and laboratory analysis under an Experimental Use Permit. The results of our research have been submitted to your agency in support of our request for an expansion of the 2,4-D label. Until your agency acts on this request, an emergency exemption is our only option.

Chemical treatment is the only option in Lake Osoyoos and the Pend Oreille River because of the lack of biological controls and the unacceptable downstream spreading of the plant which would result from mechanical control.

2,4-D is the chemical of choice because it is selective for milfoil, thus protecting valuable native species, and it is a systemic herbicide which will cause some degree of root kill. Diquat, the only other approved chemical for flowing water, would not be effective against milfoil in these areas because of the turbidity, cold water temperatures, and water hardness.

Public safety will be ensured by the contract requirements of extensive chemical monitoring, buffer zones around drinking water intakes, property owner notification, and posting of treatment areas.

Failure to treat these areas would result in significant revenue loss to local businesses dependent upon the recreation industry and would result in worse plant problems next year.

For further information concerning this request, please contact Mr. Robert Rawson, Seattle District, at telephone (206) 764-3440, FTS 8-399-3440, or Mr. Carl Brown in this office at telephone number (202) 272-0247.

Sincerely,

Ronald G. Kelsey
LTC, Corps of Engineers
Assistant Director of Civil Works,
Environmental Programs

Enclosure

[Via electronic mail]
EPA 9045
/ZIP
Regional Director HFR-01
Food and Drug Administration
909 1st Avenue - Room 5009
Seattle WA 98174,
/ZIP
Director HFF-314
Center for Food Safety and Applied Nutrition
Food and Drug Administration
200 C Street SW
Washington DC 20204,
/ZIP
WA Department of Agriculture
406 General Adm. Buld.- AX-41
Olympia Washington 98504,
/ZIP
Department of the Army
Office of the Chief of Engineers
Washington DC 20314+

Attn: LTC Ronald G. Kelsey
Assistant Director of Civil Works
Environmental Programs

The Environmental Protection Agency hereby grants a specific exemption under the provisions of section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, to the U.S. Army Corps of Engineers for the use of the dimethylamine (DMA) salt of 2,4-dichlorophenoxyacetic acid to control Eurasian watermilfoil (MYRIOPHYLLUM SPICATUM) on Osoyoos Lake, Okanogan County, Washington, and the Pend Oreille River, Pend Oreille County, Washington. This specific exemption is subject to the following conditions and restrictions:

1. The Corps of Engineers is responsible for ensuring that all provisions of this specific exemption are met. It is also responsible for providing information in accordance with 40 CFR 166.5. This information must be submitted to EPA Headquarters through the EPA Regional Office.

2. The use of the product Weedar 64, EPA Registration No. 264-2, manufactured by Amchem Products, Inc. is authorized. All applicable directions, restrictions, and precautions on the EPA-registered product label must be followed.

3. A maximum of two applications, 4 to 10 days apart, at a maximum rate of 20 lbs. acid equivalent of 2,4-D may be applied per acre. A maximum of 40 lbs. acid equivalent of 2,4-D may be applied to an acre per year.

4. Treatments will be made by certified applicators licensed by the State of Washington using a trailing hose with inverting oil or polymer.

5. Liaison should be established with the Washington State Departments of Fish and Game and/or the Fish and Wildlife Service, USDI, in order to reduce any posssible adverse effects on non-target aquatic life.

6. A maximum of 2,400 pounds acid equivalent (600 gallons of product) may be applied to 60 acres of Osoyoos Lake. A maximum of 4,000 pounds acid equivalent (1,000 gallons of product) may be applied to 100 acres of the Pend Oreille River.

7. The Corps of Engineers and/or the State of Washington will monitor the residue levels of 2,4-D and prohibit fishing, swimming and any downstream irrigation or intake of potable water until residues of 2,4-D are less than 0.1 ppm. No applications are to be made within 2,000 feet of potable or irrigation water intakes.

8. The Corps of Engineers and/or the State of Washington will notify the general public of the timing and areas to be treated via the most appropriate means of communication for announcements.

9. Residues of 2,4-D in potable water, fish, and secondary residues in various raw agricultural commodities from the proposed use should not exceed the established tolerances under Section 193.100 of Title 21 and Section 180.142 of Title 40 of the Code of Federal Regulations. Analytical methodologies are available in PAM I and PAM II.

10. The EPA shall be immediately informed of any adverse effects resulting from the use of 2,4-D in connection with this exemption.

11. A report summarizing the results of this program must be submitted by March 1, 1986.

12. This specific exemption expires on November 1, 1985.

Any future correspondence in connection with this exemption should refer to file symbol 85-DO-01.

The Agency does not anticipate currently expanding the use of 2,4-D beyond this limited use or authorizing further use of 2,4-D under section 18. The aquatic herbicide fluridone (Sonar) is expected to be registered for control of Eurasian milfoil in freshwater lakes, reservoirs, and rivers in the near future.

Steven Schatzow, Director
Office of Pesticide Programs

Date: 6/19/85

# APPENDIX E: PLANNING AND IMPLEMENTING A CONTROL PROGRAM

# PLANNING A CONTROL PROGRAM

# INTRODUCTION

A great number of factors should be taken into consideration before applying a herbicide for aquatic plant control. All operations should be part of a systematic plan that includes: monitoring of plant levels, initiation of action at a predetermined level, and review and evaluation of results of the work. The review can then be used to evaluate the effectiveness of the operation for future program modification or new program design. The plan should be sensitive to the intended use of the water body and the end user's needs. It should also be a dynamic plan that continually reevaluates the entire program and incorporates various methods and levels of control. Presented here is the framework of a decision-making process that may be used in the initial development of an aquatic plant management program or for the continuing evaluation of an established program. It may appear to be involved and cumbersome at first reading. However, once it is put into practice, the process is quite simple, and <u>it works</u>.

# PLANNING

Paramount to the whole process is the underlying objective of fulfilling the majority of the water body users' needs. Whether this is a new program or the beginning of a new direction for an old one, the planner or manager should not be ashamed to ask for opinions and help. If decisions on how to manage a water body are made on assumptions of the various users' needs, in a vacuum, then most often they will be incorrect. This results in dissatisfaction and frustration for all persons involved and, usually, costly remedial treatments. The process starts with a perceived problem. Information is then gathered from users and experts in the various fields, and a tentative plan is established. Additional coordination of the proposed plan tests the concept against the users and experts. A final plan is then developed and implemented.

## Identification of Need

The first step in the process is to identify and evaluate the need for control. In most cases, the using public will provide notification of the need for help with a new problem. When they have problems with plants, they will find out who has the responsibility for control of the offending vegetation and insist that something be done. An ongoing program should have a monitoring portion that will notify the decision makers of a developing need for control. Other managers with similar water bodies and plant management responsibility can be invaluable in helping to direct effort into productive areas. They can share the mistakes they have made and keep you from making the same ones. The various users of the area should be contacted for their opinions of the problem and possible solutions.

Care should be exercised that one particular segment of the using public does not have an inappropriate share of the input. For instance, if only the water-skier community is represented in a decision, it may appear from their view that no vegetation should be present in the water body. However, duck hunters will want most or all of the water body covered with plants to attract waterfowl. Fishermen will usually choose scattered patches of plants. The business community will most likely support the majority of their clients' views. Input from all users is essential to developing a full understanding of the plant problem, the need for control, and the degree of control that will best serve the majority of the users.

## Problem Definition

Next, a definition of the problem is in order. Is the problem the growth of the plants? Is it that these plants are different and they are not easy to fish near? Is the only problem that Mr. Jones is not able to get his boat in and out of his private canal? Concurrently with the identification of need for control, much of the information needed to define the problem will be gathered. Again, it is imperative that a good cross section of users be contacted. What some people perceive as a problem, others see as a marvelous occurrence. Duck hunters may be excited that more plants have grown in the lake so that more ducks will be attracted. Other users may not be happy to see the increase in plants. Investigate the particular plant involved and get help with identification of the plant and its potential as a weed. Gather information on the plant's attributes as well. It could be that the plant is an important part of the fisheries of the water body. Consult with game and fisheries biologists and ask their opinion. Seek books and scientific articles on the plant and its association with the environment. Read this information and use it to help in deciding what the problem or problem potential really is.

From all the information collected, a converging direction should become evident. A synthesized problem definition can then be put together. The problem could be that "lower than usual water levels have caused native plants to spread beyond their usual bounds, and boaters are having difficulty traveling their normal routes." It could also be that "a new plant has been introduced into the water body and it is an exotic weedy species." The proposed problem definition should then be tested against the same group from which you originally requested information. Of course you will never get everyone to agree with a problem statement; but, the statement should be modified until it will meet with the majority opinion. Perhaps the finalized version of the first statement above would include "and favorite fishing spots have become inaccessible." This becomes the final statement of the problem and a definition of the puzzle that must be solved.

## Development of Solution

To develop a solution to this problem, you must again draw on as many sources as possible. Call on the users, businesses, peers, and agency professionals for possible solutions. Resist the temptation to tell them why you think the idea will not work and encourage them to give you as many potential solutions as they can. Search your own mind and try to think of ways to solve the defined problem. Make a list of all the proposed solutions as you collect them so that you do not forget some important ones. Try to cover all possible methods of solving the problem, including the ridiculous. Sometimes what appears ridiculous at first can be used as a part of the solution. Superfluous solutions will be eliminated later in the process. Of course, you should explore each of the classical methods: mechanical, chemical, biological, and habitat manipulation. Some other categories you may wish to consider are no action at all and cultural changes. An example of cultural change would be helping fishermen to learn to use the new vegetation to increase their catch. Another example would be helping water skiers realize that a border fringe of plants will not seriously affect their sport while it will help fishing for their friends.

After developing a large list of possible solutions, begin the elimination process. This is done by working up a set of parameters within which to operate. These are the conditions over which one has no control but which exert some measure of control over the feasible options. Probably the most important is the authorities under which the work can be performed. For example, Mr. Jones' private canal is not within the Corps' authority for plant control; therefore, Mr. Jones will have to take care of his problem. Proposed control options must also be consistent with laws and regulations, such as the National Environmental Policy Act and the Endangered Species Act. For the Corps and other Federal agencies, this means that a specialized, formal, documented decision-making process must be adhered to as set forth in the laws and Corps regulations. The next logical constraint is financial. Within the Corps, a project must be economically justified before it can be implemented. Benefits to be realized must outweigh costs of the operations. The amount of funds currently available or anticipated will certainly limit the options available and their viability. Possible adverse effects that a control option may have on fish and wildlife must be considered. Options that have unacceptable adverse effects must be discarded.

The potential solution's effectiveness should be considered very carefully under the conditions which it must be used. Water body type has a definite effect on herbicides that can be used. Products are labeled for specific types of water bodies. Use of the product in any water body not specified on the label is considered a misuse and is illegal. Some formulations of herbicides are ineffective in moving water, although they may be labeled for this use. The season when the work can or should be performed may affect the ability of some products to adequately control the target plants or their effects on nontarget species.

Public acceptance is an important consideration in the development of possible solutions. Public opinion can have very strong influence on the ultimate selection of the control method used and just how and where it will be used. A feeling for public sentiment will have been acquired during the processes of identifying the needs and problems. This knowledge should be used in selecting the plan of action. This is not to say that public opinion should be the overriding consideration in planning the program. However, areas where the plan may deviate from general opinion must be thoroughly understood. An acceptable logic for the selection should be on hand for use in defense of the plan. This defense should be factual, easy to understand, and true, for it may have to be used to educate the public.

Using the list of possible solutions and testing them against the list of limitations should result in a much shortened version of the list. For instance, you may wish to use a mechanical harvesting system to cut trails for a portion of the plan. Many of the requests for input from others could have also indicated a strong support for this method. You may find that the areas proposed for trails were not completely cleared of trees when the pool was flooded, so that mechanical systems could not be relied on to effectively clear trails. From the list, a single option or group of options can be chosen for the test solution. At this stage, the solution is conceptual and is used as such. The concept is tested with peers and by consultation with others. Public meetings are another excellent way to test the concept. It is the using public that is to be served, and their assistance in the design of the plan at this stage will better ensure their satisfaction with the completed work. It also provides an opportunity to explain the decision-making process that has been used and the constraints under which the project must operate. The plan can now be finalized. Changes that are justifiable can be made to the conceptual plan, and the details of implementation can be worked out.

## OPERATIONS

### General

The details of the work plan will include who will perform the work, how it will be done, and generally who is responsible for what. If the work is to be performed by in-house labor, a schedule of when the chemical will be ordered and delivered, when the work will be performed, and specifically which plants will be treated should be a minimum planning effort. After repeated applications, the plan should have evolved into a streamlined statement of an efficient operation. Moreover, the work crews will have developed a knowledge and skill level that will allow them to know the criteria for the effective and efficient treatment of plants. As always, a fine-tuning process comes about through repetitive operations.

The method of application is usually dictated by the size of the area to be treated and the availability of equipment and skilled personnel. Small areas can easily be treated from a small boat with pellets or granular products. There is no mixing of chemicals involved, and the application does not require specialized equipment. A compressed air sprayer with a capacity of 1 or 2 gal can also be used to treat small patches of emergent or floating plants.

As the size of the area or areas to be treated increases, the complexity and demands on equipment and personnel increase. Treatment of large masses of submersed or floating plants usually requires the use of an airboat. The usual problem of weeds fouling the conventional underwater propeller is eliminated by the airboat. A specialized application system that includes modified agricultural spraying equipment is then installed in the airboat to apply liquid formulations of herbicides. Special water wells mounted to the hull of the boat are used to draw water directly from the water body and, in many instances, the chemical is automatically injected into the system. After such a system is set up, the applicator must only make sure that the chemical container is not empty and can make continuous treatment without stopping to mix chemicals.

For very large areas of treatment, aerial application is usually most cost effective. The equipment and specialized operators would seem to be very expensive. However, an airplane or helicopter that is equipped to treat vegetation with herbicides can easily treat hundreds of acres a day. This allows the aerial applicator to distribute operating costs over greater acreage and results in an overall cost savings. Several very important things must be considered in the selection of aerial treatment. The areas to be treated must be large, connected areas. It is inefficient to aerially treat a large number of small patches of plants. The craft is moving so fast that it is almost impossible to turn the spray system on and off to cover the patches of plants. It is also difficult to treat small fringes of plants along shorelines when there are trees, docks, and other obstructions or frequent irregularities along the shorelines.

Airplanes can treat greater amounts of plants in a shorter time than a helicopter under certain conditions. However, they usually treat at a greater speed and cannot maneuver as easily over irregularly shaped areas of plants. More importantly, planes need a long runway to take off and land for filling the spray tanks, whereas helicopters can operate from a relatively small open area. Planes will spend a lot of time traveling back and forth to the airstrip unless there is a serviceable airfield near the treatment site. Helicopters are able to use much smaller areas to land and take off, so they can usually operate much closer to the actual treatment site. Time loss for the helicopter ferrying to the loading site is, therefore, much less. Be careful in the selection of locations for a helicopter to operate. Most helicopters cannot take off straight up with a load and require an open area or short runway for takeoff. This area does not have to be paved or even smooth-surfaced, but it should be clear of trees, power poles, and other obstructions.

## Contracts

Aerial application is beyond the ability of most organizations to support, and is usually contracted. Of course, contracting is the best choice when the job exceeds in-house capability and does not warrant "gearing up" for a continuing program. Your organization's contracting element will usually handle the administrative burden of advertising and awarding the contract. However, as the element responsible for the operations, you must decide what work will be contracted and write up the specifications or technical provisions of the contract. The actual equipment required and method of treatment should have already been decided in the conceptual plan. These will be the equipment and method specified in the contract technical provisions. Herbicides and adjuvants to be used can be included in the contract as to be provided by the contractor, or they can be purchased separately and provided to the contractor. If it is uncertain exactly which products will be used or if it appears more economical to provide the materials from existing stores, the contract should be written with the Government providing the chemicals. Otherwise, the contractor should provide the chemicals.

Several other things should be included in the plan for contracting. There are always delays built into the contracting process. Certain steps must always be followed by the procurement personnel to advertise and award the contract. Time must be allowed for the prospective contractors to prepare their bids and for processing of the award. Talk with the procurement personnel and get a good estimate of the time between when they get your request for contract and when you can expect to have a contractor on the job.

Use this information to plan when your request must be submitted to procurement. Also, send in a request for wage rate determination, since this may require up to 6 months.

The measure of the work to be performed and payment units must be decided upon and estimated. The job may be paid for in a lump sum upon completion. This may be a convenient payment method for a small job. Larger jobs could be estimated and paid for on a lease plan. Payment units in this case would be by the hour of operating time. An allowance for time during which the contractor has his personnel and equipment on the job but cannot perform because of adverse conditions, such as weather, should be included as lay time. This type of contract lends itself to operations where the Government will be providing the materials to be applied. It is also easy to measure the amount of work performed on an hourly basis.

This type of contract can be used in a little different form if the contractor will be providing the chemicals. The actual materials that are specified can be added to the unit price schedule and paid for at the bid price, as they are used by the contractor. It is not uncommon to try to advertise and award a contract with a unit of measure and payment of acres treated. The difficult part of this type of contract is the measurement of the area after treatment and agreement between the contractor and Government of just what work has been performed. In the aerial application business it is not uncommon to bid jobs on a gallons-applied basis. The unit of payment would then be based on the gallons of spray mix that the contractor applied at the contract-specified mixture and application rate. This could easily be measured by a meter between the mix pump and the aircraft's hopper.

The contractor should be responsible for any state and local permit requirements and necessary certification of personnel. This requirement should be included in the specifications. Any other matters of responsibility that may be open to interpretation should be specified, e.g., responsibility for triple-rinsing and disposing of empty herbicide containers. If the Government will locate and secure approval of landowners or owns land that will be used as the base of operations, it should be so stated in the contract specifications. Otherwise, the responsibility for acquiring land use should be stated as belonging to the contractor.

## COORDINATION

The public should be notified just before control operations begin. Of course, the public meetings would have given prior notice that operations were being planned, and perhaps the approximate dates were discussed. However, these dates were tentative, and the public has a tendency to forget proposed dates. To eliminate the appearance of deception and to promote good will with the using public, some additional form of notification should be used.

The enforcement of Title 40 by the USEPA also requires the applicator to make a reasonable attempt to let people know if the application may affect them. The precautionary statements on the herbicide label can serve as a guide for notification. If the label states "Water is not to be used for irrigation for seven days following treatment," the applicator must ensure that persons who may use the water for this purpose know about the limitation. Other precautions listed on the label should likewise be placed on notifications.

Several methods of notification can be used, depending upon local conditions. Different methods of notification may need to be used in the same water body at different locations. There are no standards for notification procedures. The determining factor as to your legal satisfaction of notification is whether or not the effort expended to notify the potentially affected public was reasonable. Public notices can be published in the local newspaper to inform the users of precautions. Signs can be erected at the treatment site and/or at access points to the water body to notify users of the treatments. A system of markers or buoys can be used where treatments will be made on a recurring basis and the majority of the users are local. For instance, special-colored buoys could be placed to outline treatment areas. Notices could initially be affixed to the buoys as well as at strategic locations around the water body to describe the purposes of the buoys and the precautions. Later, the number and detail of the notices could be reduced. Frequent users would become familiar with the system and the meaning of the buoys.

Most of the precautions on the chemical labels have a specified time interval following treatment during which water use is restricted. Provision should be made to indicate this time period in the notification. Date of treatment may be posted on signs, with a statement of the time period the water usage is restricted. Another method is to state the ending date for the restricted uses. Of course, the signs could indicate only the water use restrictions, with no time specified. Then the signs could be removed at the end of the restriction period. This may not be the best method, however. If the signs are not picked up on time, the public may be kept from legitimate use of portions of the water body. The small added effort to date the signs would eliminate this problem.

Whether the work is performed by Government or contract personnel, a pre-work briefing should be held to make sure that all parties understand the assignment of responsibilities. Applicators should be advised of the safety and use precautions on the herbicide label. Other general safety precautions both in the handling and application of the chemicals, as well as use of equipment, should be stressed. Any special conditions to be found in the treatment areas or any areas to be specifically excluded from treatment should be discussed and understood by the applicators. Considerations expected for users of the project area while applications are being made should also be discussed. Any questions the applicator may have about the operation should be cleared up during these meetings.

## PROGRAM MONITORING

The job is not completed when the last of the chemical is applied to the lake. Aquatic plant control is similar to the maintenance of a lawn. It is a continuous program over the growing season. Additional treatments may be necessary in order to maintain the plants at an acceptable level. There are, however, certain things that should be done following treatment.

With any systematic operation a feedback loop is needed. This feedback allows the program manager or field foreman to keep track of the success or failure of the program goals. It also allows him to determine the effects of operational changes to the program and the effectiveness of various management options. Feedback may come from a variety of sources. It could be that the manager waits until he hears that something has gone wrong. We will call this the default approach. Or, a program of reporting and inspection could be used for feedback. Let's call this the planned approach.

## Default Approach

Often, in the haste of starting a program, it is easy to accept the default approach. There seems to be more work than can be accomplished. Many ways of getting the job done must be sorted through, and the decision to do it a certain way must be defended to many people. In all this confusion, it is easy to forget that someone must monitor the program as it is being performed. This portion of the plan can be accidentally omitted, which gives rise to the default approach.

Consider this situation: The program begins and everything seems to be running smoothly. A few situations arise that require minor changes in the plan, but overall the people that planned the program are feeling satisfied. No symptoms of major problems come to light, so the program manager assumes all is well. Then, one morning when he comes to work, he is besieged with telephone calls. It seems that the work crews have been treating an area around an intake for the lawn sprinkling system of a subdivision. Every time they make an application, the lawns turn brown. The homeowners know that the treatments keep their lake usable, but they have finally become fed up with the problems it causes with their lawns. They have called their attorneys, their congressmen, and the newspapers. The headline in the morning paper reads "Government Agency Poisons Innocent Homeowners' Lawns." Your immediate response is "There is nothing I could have done to stop this." This is a representative result of the default approach. No effort was made to test how well the system was working, so the assumption was made that it was alright. The public you serve should let you know if things are not going right. In reality, they will not, unless something is terribly wrong. They will suffer the minor problems silently. Finally, when they feel "fed up," they SCREAM. Not to you, as you would like, but to everyone who could cause you problems. You then must spend considerable effort to resolve the situation.

## Planned Approach

Let's look at the above situation through the eyes of the manager that chose to use the planned approach. He has an inspection program in force on all of his fieldwork. The field foreman looks over each of the treatment sites before they are treated and schedules the work crews to make best use of the resources. Following the application, he returns to the site to evaluate the effectiveness of the treatment. He works closely with the field crews and the manager. He has the authority to make field changes that have saved thousands of dollars and many headaches. The manager is aware of what the existing field conditions are because of the reports that are provided him by the foreman. The manager understands human nature and designs his program to work in the real world. He has his field foreman stop by the local fish camps and community centers and talk with their customers, the using public, on a regular basis. One of the people told him that their lawn was dying and they thought that it was because of the spraying. The foreman investigated the situation and found that the developer had installed a lawn watering system that drew water from the lake. The developer had not notified anyone that he would be drawing water from the lake, and the intake was not visible from the water. The foreman notified the manager of the situation and suggested a remedy. The plan for treatment of this area has been changed. The work crew notifies the development maintenance office before they treat the water. The maintenance office notifies the homeowners when the treatment will be made. Water is not drawn from the lake for 3 days after the treatment, in accordance with the herbicide label. There has been no more trouble with the lawns since this procedure has been implemented.

This is an example of how creative methods of collecting feedback can be very helpful for early warning of problems that are developing. The effectiveness of the treatments and customer satisfaction can, likewise, be measured through frequent contacts with the using public. This serves as additional input to the feedback system and can be used to verify or support input from other sources.

## Inspections

It is unlikely that the usual feedback of report forms or inspection reports would have revealed the problem depicted above, but they are just as important. There are a number of ways these inspections can be performed. Probably the best inspection is an onsite review by the field foreman or program manager. This is also the most costly and time consuming. There are very few organizations that can afford to have someone to personally review all operations. There is no replacement for an on-the-ground look at where the work is being performed. This is the only way to get a true feel for the quality of the work that has been performed and the resulting plant control. All plant control programs ought to have some onsite inspection. The amount, however, will usually be determined by funding and personnel limitations.

If it is impossible to have all work personally inspected, some form of scheduling should be used to get the most benefit of the effort expended. Initially, some form of pseudo-random inspection could be used. The objective should be to review all crews' work, each of the work areas, and all types of treatment within some predetermined time period. For instance, each of the work areas should be inspected a minimum of once each treatment season. Likewise, each of the work crews' operations should be reviewed at least once a season, and these inspections should be scheduled to allow the evaluation of each of the different types of control being used. This is an absolute minimum inspection program and would certainly not be very sensitive. If symptoms of problems are seen during this inspection program, additional inspections can be performed in the problem area to verify the initial findings.

Aerial inspections can be a very important part of the total feedback. This is particularly true of very large programs that cover many water bodies. A light, high-winged airplane such as a Cesna model 172, 182, or 210 is probably best for this job. The plane can be chartered to fly an observer over the water bodies. The observer records the presence of plants and other pertinent information on maps. These are later used to reconstruct the inspection in a written report. The field foreman or the manager could perform the aerial inspection, or they could alternate. This would allow each of them to have an overall picture of the condition of the program water bodies. The greatest advantage of the aerial inspections is that a person is able to cover an enormous area in a single day. Hundreds of miles of shoreline can be scanned in one-tenth the usual time. The program manager or foreman is able to get an idea of the condition of all the water bodies under his responsibility in just a day or two. The cost for the plane charter is insignificant compared with the benefit derived in this short period.

## User Input

There are other methods of collecting feedback on the program. Numerous special interest groups are on the water continually. Bass fishing clubs have tournaments regularly, and their members are constantly practicing for the tournaments. Fishing guides usually know each other well and may even have joined together to form their own organization. Water-skiers, hunters, bird-watchers, and other people that have common interests will form clubs or other organized groups to share their interests. Each of these groups is watching the water body from a different perspective, but they have one thing in common. They will notice when something goes wrong that may affect their special interest and will do their best to keep it from happening again. These groups can be a valuable source of information on the condition of the water body and the observed effects of treatments. Their executive officers represent a large group of people and can be an effective avenue of communication. The manager should find these groups and establish a good working relationship with them. Information that they provide can be quite useful, and it is free!

## Incidental Input

If there are other elements within your organization that routinely inspect or survey water bodies, you may be able to get them to look for obvious aquatic plant problems at the same time. When you perform an inspection or survey of an area, you could likewise be observant for their area of concern. This way, each of you could benefit from the other's time in the field and cover greater areas with fewer resources.

## Operational Reports

Some type of operational report form ought to be mandatory for all herbicide applications. The completed forms are essential for documentation of the work performed. This allows the manager to evaluate the performance of the various options of control that were used. He can take the work reports into the field and use them as the basis of determining effectiveness. Probably the most pressing need for operational reports is for defense against claims. When a legal claim is brought against your organization, the operational work reports are your first line of defense. These will become your documented evidence, sworn to by the persons performing the work, of exactly what was done on the day or days in question. This evidence carries a lot of weight compared with the claimant's recollection of events.

The forms should be designed with this in mind. Spaces ought to be provided on the form and labeled for the specific types of information that would be useful in defense of a claim. The minimum information that should be included is type and amount of herbicide that was used; types and amounts of any additives to the spray mixture, including dilutant; the specific site of application; weather conditions, particularly wind speed and direction; information regarding distribution of time over the various tasks involved in the operation; and notations of any special conditions or unusual occurrences. If the program is large enough and the number of reports great enough, a computer program may be in order to compile the data into useful information.

## HERBICIDE AND CONTAINER DISPOSAL

Other things must be done following treatment. Equipment must be cleaned and maintained. Empty herbicide containers must be disposed of properly. Empty containers can be a problem if they are not handled properly for disposal. As long as the containers are being used to store the product for use, they are regulated under the US Environmental Protection Agency's Federal Insecticide, Rodenticide, and Fungicide Act (FIFRA) as a herbicide container. Once all the herbicide has been drained for use, the container may become a hazardous waste depending on how it is handled. As a generator of hazardous wastes, you will have to follow a different set of regulations, which include keeping an inventory of waste materials and records of their proper disposal. Disposal of this hazardous waste becomes a very involved and costly process. However, there is no need to get into this situation. Proper disposal procedures are written on the label of the container. Most liquid containers, once they are triple-rinsed, are no longer considered contaminated and will not have to be handled as a hazardous waste. For instance, a 5-gal pail may have the instructions to "triple rinse, puncture the container, crush and bury in a landfill." This means that three times this container must be filled approximately 1/4 full of dilutant, swirled or shaken vigorously to wash the interior, and drained. The container must then be punctured and crushed. It can then be buried in a landfill. If any of the intermediate steps are neglected, you may have broken the law. The material used to rinse the container is considered to be contaminated. Disposal of the rinsate is covered later in this section. Bags and boxes that contained dry materials, such as granules, pellets, or powders, can sometimes be burned. Check the label for disposal instructions. FOLLOWING THE INSTRUCTIONS THAT APPEAR ON THE LABEL IS YOUR ASSURANCE THAT YOU ARE LEGALLY DISPOSING OF THE CONTAINER.

Care should be used in the cleaning of equipment. The water used to clean equipment becomes contaminated and must be disposed of in the same manner as a herbicide. The pesticide label has instructions for the proper disposal of the product. The easiest and cheapest way to dispose of contaminated water is to use it in the spray mix. The contaminated water may be used as the dilutant in the spray mix. The product is thereby being legally used as specified on the label. This is also the best way to dispose of a herbicide; use it for treatments as it was labeled.

## OTHER CONSIDERATIONS

### Residue Monitoring

If the herbicide label has use restrictions that are tied to the residue level of the herbicide, a residue monitoring program may be in order. The label may state that "water should not be used for irrigation for seven days following treatment or until an approved assay shows levels to be less than 0.01 parts per million." If there is a need for use of the water before the 7-day limitation, a sampling and analysis program could be used. If this assay shows the water to have less than the specified residue, it can be used sooner. A residue monitoring program is a very expensive proposition. It is not uncommon for a single herbicide analysis to cost $100 or more. This does not include the cost of collection, storage, and transport. There may also be considerable difficulty in finding a laboratory that is not so backlogged with work that they can run your samples in the usual time that the water is restricted.

### Water Quality

Water quality monitoring of some sort may also be needed from time to time. Probably the most frequently monitored parameter is dissolved oxygen (DO). Herbicide-treated plants will consume oxygen as they decompose. The chemicals themselves may alter oxygen levels in the water. Animals that live in the water rely on the oxygen that is dissolved in the water as their source of this gas. If the levels drop too low, these animals will die unless they are able to move to other areas where the oxygen levels are higher. Sometimes the DO level in natural water bodies may dip low enough to kill fish and other animals. Other times the oxygen level will hover dangerously low for extended periods. Normally there is sufficient oxygen to handle the added load of the decomposing plants. Fish will most certainly be killed if treatments are made when the DO level is too low. Field DO meters can be helpful in determining when oxygen levels are so low that treatment could kill fish.

## Cleanup

If signs or buoys have been used to notify water body users of water use restrictions, they should be removed soon after their expiration date. This may not be a legal requirement, but it will certainly help with your public image. No one likes to see a lake or river that is strewn with buoys, stakes, and signs. If the people are already sensitive to the use of chemicals in the water, these old markers will only serve to annoy them further. Care must also be exercised to clean up any other areas that are disturbed during the application. Courtesy exhibited by your field personnel will be repaid several-fold when some other minor problem is excused by your public.

This is by no means a complete description of things that will need to be done following treatment. With each water body, each region, each group of specialized waterway users, there are special conditions that must be met by the treatment program. There are, likewise, special monitoring and follow-up needs that will have to be addressed. The purpose of this discussion is to give some ideas of how a well-coordinated program could be set up. It is also a challenge to those who have been in the aquatic plant control business for some time to look carefully at existing programs and consider if they need to be updated. A well-conceived program that is planned with the input of the customers, carried out with their interests in mind, and modified when it misses the mark should be the goal.

# APPENDIX F: ECONOMICS OF HERBICIDE SELECTION

# ECONOMICS OF HERBICIDE SELECTION

The cost of chemical control operations includes a number of separable elements: herbicide, length of control, labor, travel, equipment, and supervision and inspection. The selection of the herbicide to be used may have the greatest effect on the overall cost of the control effort. Some herbicides may well exceed the total cost of the remaining elements put together. Other herbicides could be a minor constituent of the total control cost.

The average cost to apply chemicals is in the range of $36 to $55 (1987 dollars) for each acre of plants treated, exclusive of the cost of the herbicide and adjuvants. The cost of chemicals currently ranges from $3.50 to $480.00 for each treated acre. The first logical choice would appear to be the least expensive product available. However, there are other considerations in making the best choice for the job at hand. PROBABLY THE MOST IMPORTANT PART OF SELECTING A HERBICIDE IS TO MAKE CERTAIN THAT THE PRODUCT IS EFFECTIVE ON THE TARGET PLANT UNDER THE CONDITIONS THAT IT MUST BE USED.

Several herbicides may be available that have enough differences in their activity to make it worthwhile to select one over the other. A difference of 10 to 20 percent in effectiveness could well mean that additional applications may be necessary for season-long control. This will result in added cost for the additional herbicide treatment. Duration of control is likewise important in determining the most economical herbicide. Contact herbicides may only "mow" certain plants back to the water or sediment/water interface. Plants are then able to resprout from remaining, unaffected, plant parts. A herbicide that is systemic, i.e., translocated through the plant, will likely kill all parts of the contacted plant. This will result in considerably longer control. A herbicide may appear to exhibit residual effects through this systemic action. Slow-release herbicide formulations will release low levels of the contained herbicide over a period of time. This may allow for control activity in areas where water currents would otherwise dispense the herbicide too quickly.

Ease of use should be considered in selecting a herbicide because of the possible effects on cost. Some herbicides require special equipment and/or training for their application, and these products will have the added cost of this equipment or training for the personnel. Ease of storage and transport of the product can also significantly affect the economics. If a job calls for only a small quantity of herbicide and the herbicide is only available in 30- or 55-gal containers, special handling and storage space will have to be provided. An alternative product that is just as effective and that is available in smaller containers would eliminate these associated costs.

Type and amount of carrier that is needed can also affect the cost. Dry products, such as pellets and granules, typically have a low percentage of active ingredient and a high concentration of inactive carrier such as clay. A large part of the shipping cost for the product and storage space will be for the clay carrier. Also, the capacity of the usual size truck and/or boat that is used by a work crew may be inadequate to carry a 1-day supply of materials with the added weight of the carrier. Larger sized or additional vehicles would be necessary to carry a day's supply of chemical, or the number of treated acres per day would be reduced. Either way, this would result in added costs.

Liquid herbicides usually have higher concentrations of active ingredients. Highly concentrated formulations reduce shipping and storage costs. More active ingredient can be hauled and stored in the same space with less weight. Transporting a day's worth of herbicide does not require special or additional equipment. However, the user should be careful that a requirement for special dilutants or additives (adjuvants) does not eliminate this advantage. For aquatic applications, water is easily available at the application site.

Products that use water as the dilutant have advantage over others. If the dilutant is oil or combinations of other products, this must be carried to the work site on the truck and/or boat. Some liquid products, particularly ester formulations, require a form of oil for the dilutant. Others may require an oil and an emulsifier, as well as water, to form an invert emulsion for application. Anytime additional material is needed in the spray mix, the cost of the application is increased because of special shipping, storing, and handling requirements for the additional materials.

The amount of herbicide required to treat an acre of vegetation will vary considerably from product to product. Cost of the total amount of product necessary to treat an acre should be used in making comparisons. A potential product may be deceptively inexpensive. For instance, if product A costs only $10 a gallon and product B costs $50 a gallon, it would seem that product A would be more cost effective. However, if it takes 4 gal of product A to do the same job as 0.5 gal of product B, then the reverse would be true. Likewise, granular formulations of the same active ingredient may be more expensive than liquid formulations on a cost per unit active ingredient basis. Granular products may have a purchase price of nearly $1 per pound, while liquid formulations may cost many dollars for a gallon. Remember that granular formulations usually are ready for application and have a low concentration of active ingredient. Thus, with the same application rate of active ingredient, the granular product would be more expensive.

There may be several herbicides that can be used to control a particular species of plant. One or two may be better from an economic standpoint. The product that is the easiest to use, requires little or no adjuvants, and is effective over a long period of time is usually the most economical even though it may appear to be the most expensive initially.

# APPENDIX G: APPLICATOR'S DAILY SPRAY REPORT AND BIDDING SCHEDULE

APPLICATOR'S REPORT

WEEKLY REPORT OF OPERATIONS
AQUATIC PLANT CONTROL

Crew No. 1 (1-5) Period (6-9) thru (10-13) 19 (14,15)

Watershed and Area ____________ (16-20) County ____________ (21,22)

Cost Account No. (23-27) (28-32) (33-37) Kind of Vegetation (38) Method of Control (39)

| ITEM | | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Totals CC 1 2 |
|---|---|---|---|---|---|---|---|---|---|
| Equip Rental (hrs-min) | | | | | | | | | 14 |
| | | | | | | | | | 20 |
| | | | | | | | | | 26 |
| | | | | | | | | | 32 |
| Vehicle Usage | | | | | | | | | 38 |
| | | | | | | | | | 43 |
| Crew Time (Hrs.) | | | | | | | | | 48 |
| | | | | | | | | | 52 |
| | | | | | | | | | 56 |
| Per Diem Name & Account | | | | | | | | | 60 |
| | | | | | | | | | 65 |
| | | | | | | | | | 70 |

| Time Distribution | Sun | Mon | Tue | Wed | Thu | Fri | Sat | CC 1 3 hr. min. |
|---|---|---|---|---|---|---|---|---|
| Effective Time | | | | | | | | 14 |
| Travel Time vehicle | | | | | | | | 18 |
| Travel Time plant | | | | | | | | 22 |
| Lost Time rain | | | | | | | | 26 |
| Lost Time wind | | | | | | | | 30 |
| Minor repairs (explain) | | | | | | | | 34 |
| Major repairs (explain) | | | | | | | | 38 |
| Other duties | | | | | | | | 42 |
| Holiday or leave | | | | | | | | 46 |
| Survey | | | | | | | | 50 |
| Inspection | | | | | | | | 54 |
| Preparation | | | | | | | | 58 |
| Removing obstructions | | | | | | | | 62 |
| Miscellaneous (explain) | | | | | | | | 66 |
| Total time in period | | | | | | | | 70 |

| | Sun | Mon | Tue | Wed | Thu | Fri | Sat | CC 1 4 Herb. Amt. |
|---|---|---|---|---|---|---|---|---|
| Herbicides and Amount | | | | | | | | 14 |
| | | | | | | | | 20 |
| | | | | | | | | 26 |
| | | | | | | | | 32 |
| | | | | | | | | 38 |
| Diluent & Conc. | | | | | | | | |
| Acres Controlled | | | | | | | | 44 |
| Wind Data: Time | | | | | | | | |
| Wind Data: Direction | | | | | | | | |
| Wind Data: Velocity | | | | | | | | |

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|---|---|---|---|---|---|---|
| | | | | | | |

Remarks

Submitted: ____________________ Approved: ____________
Crew Chief

SAJ Form 454
26 Jun 78

## COUNTY CODES

11 - Alachua
52 - Baker
23 - Bay
45 - Bradford
19 - Brevard
10 - Broward
58 - Calhoun
53 - Charlotte
47 - Citrus
48 - Clay
64 - Collier
29 - Columbia
1 - Dade
34 - DeSota
54 - Dixie
2 - Duval
9 - Escambia
61 - Flagler
59 - Franklin
21 - Gadsden
55 - Gilchrist
60 - Glades
66 - Gulf

56 - Hamilton
30 - Hardee
49 - Hendry
40 - Hernando
27 - Highlands
3 - Hillsborough
51 - Holmes
32 - Indian River
25 - Jackson
46 - Jefferson
62 - Lafayette
12 - Lake
18 - Lee
13 - Leon
39 - Levy
67 - Liberty
35 - Madison
15 - Manatee
14 - Marion
42 - Martin
38 - Monroe
41 - Nassau

43 - Okaloosa
57 - Okeechobee
7 - Orange
26 - Osceola
6 - Palm Beach
28 - Pasco
4 - Pinellas
5 - Polk
22 - Putnam
20 - St. Johns
24 - St. Lucie
33 - Santa Rosa
16 - Sarasota
17 - Seminole
44 - Sumter
31 - Suwannee
37 - Taylor
63 - Union
8 - Volusia
65 - Wakulla
36 - Walton
50 - Washington

## VEGETATION TYPE

1 - Hyacinth
2 - Alligatorweed
3 - Hydrilla
Eurasian Water-
4 - milfoil
5 - Cattails
6 - Water lettuce
7 - Hyacinth-water lettuce mix
8 - Melaleuca
9 - Other

## METHOD OF CONTROL

C - Chemical
M - Mechanical
B - Biological

## EQUIPMENT

1 - Airboat
2 - Aircraft
3 - Kickerboat
4 - Harvester
5 - Transporter
6 - Elevator
7 - Dump Truck (Harvester)
8 - Trailer with Tank
9 - ATV Platform
10 - Underwater Cutter
11 - Tank Truck (Aircraft) 2-1/2 ton
12 - Spray Truck (Invert 2-1/2 ton)
13 - Batch Truck - 1 ton
14 - Flat Bed Truck - 2 ton
15 - Flat Bed Dump Truck - 2-1/2 ton
16 - Tractor (Semi-Truck)
17 - Tilt Trailer - 12 ton
18 - Low Bed Trailer
19 - Dragline
20 - Towboat
21 - Other
22 - Barge
23 - Pontoon Boat
24 - 20 Foot Motorboat
25 - Helicopter

## HERBICIDES

(liquid in gallons; granular in pounds)

1 - 2,4-D Amine
2 - Diquat
3 - Copper Complex
4 - Hydrothol 191
7 - Other
8 - Invert Oil
9 - Diesel
11 - Aquathol-K (liquid)
12 - Sonar (liquid)
13 - Sonar (granular)
14 - Aquathol granular
15 - Polymers
16 - 2,4-D granular
17 - Other adjuvants
18 - Rodeo

## VEHICLES

1 - Sedan
2 - Station Wagon
3 - P.U. Truck-1/2 ton
4 - P.U. Truck-3/4 ton
5 - P.U. Truck-1 ton
6 - Blazer, Carryall, 4x4 wagon
7 - Other

BIDDING SCHEDULE "A"

(To be attached to bid)

| I 1 NO. | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT PRICE | ESTIMATED AMOUNT |
|---|---|---|---|---|---|
| 1 | CONTRACTOR FURNISHED AIRBOAT, SPRAY SYSTEM, AND CREW | | | | |
| | A. CREW OPERATING TIME | 1600 | HRS | ----- | --------- |
| | B. AIRBOAT OPERATING TIME | 1400 | HRS | ----- | --------- |
| | C. AIRBOAT LAY TIME | 200 | HRS | ----- | --------- |
| 2 | TRANSPORT TRUCK WITH BOAT TRAILER | | | | |
| | A. OPERATING TIME | 200 | HRS | ----- | --------- |
| | B. LAY TIME | 1400 | HRS | ----- | --------- |
| 3 | ADVERSE WEATHER LOST TIME | 160 | HRS | ----- | --------- |
| | HERBICIDES AND SPRAY ADDITIVES TO BE FURNISHED BY THE CONTRACTOR | | | | |
| 4 | 2,4-D AMINE AQUATIC HERBICIDE | 300 | GALS | ----- | --------- |
| 5 | DIQUAT HERBICIDE | 400 | GALS | ----- | --------- |
| 6 | CHELATED COPPER COMPLEX | 400 | GALS | ----- | --------- |
| 7 | RODEO HEBICIDE | 50 | GALS | ----- | --------- |
| 8 | AQUATHOL-K HERBICIDE | 1200 | GALS | ----- | --------- |
| 9 | NALQUATIC AQUATIC HERBICIDE CARRIER | 800 | GALS | ----- | --------- |
| 10 | NON-IONIC SURFACTANT TO BE USED WITH RODEO SPECIFY NAME:____________________ | 36 | GALS | ----- | --------- |
| | | | | TOTAL | |

NOTE: THE GOVERNMENT RESERVES THE RIGHT, AT ITS OPTION, TO FURNISH ANY OR ALL OF THE ITEMS 4 THRU 10 ABOVE IN LIEU OF PAYMENT TO THE CONTRACTOR.
ALL BIDS MUST BE FOR THE ENTIRE WORK AND MUST HAVE EACH BLANK SPACE FILLED IN.
THE TIME AND/OR QUANTITIES SPECIFIED ARE THE GOVERNMENT'S BEST ESTIMATE OF THE AMOUNT REQUIRED. HOWEVER,THE CONTRACTOR WILL BE PAID FOR THE SERVICES AND/OR SUPPLIES ACTUALLY USED,BE IT MORE OR LESS THAN THE QUANTITY SPECIFIED.

# APPENDIX H: JOURNALS ON AQUATIC PLANT MANAGEMENT

JOURNALS ON AQUATIC PLANT MANAGEMENT

Aquatic Botany

Elsevier Science Publishers
PO Box 330, 1000 AH
Amsterdam, Netherlands

Aquatic Toxicology

Elsevier Science Publishers
Biomedical Division
PO Box 211, 1000 AE
Amsterdam, Netherlands

Aquatics

Aquatics Magazine
7922 NW 71st Street
Gainesville, FL 32606

Archiv Fur Hydrobiologie

E. Schweizerbart Verlagsbuch, Nagele U.
Obermiller Johannesstrasse 3A, D-7000
Stuttgart 1, Fed. Republic of Germany

Australian Journal of Marine and Freshwater Research

Commonwealth Science and Industry Research Organization
314 Albert St.
East Melbourne, Victoria 3002, Australia

Bulletin of Environmental Contamination and Toxicology

Springer Verlag
175 Fifth Ave.
New York, NY 10010

Canadian Journal of Botany

National Research Council of Canada
Ottawa, Ontario
Canada KIA OR6

Canadian Journal of Fisheries and Aquatic Sciences

Department of Fisheries and Oceans
Scientific Information Public. Branch
240 Spark St.
Ottawa, Ontario, Canada KIA OE6

Estuaries (previously Chesapeake Science)

Estuarine Research Federation
PO Box 368
Lawrence, KS 66044

Freshwater Biology

Blackwell Scientific Publications, Ltd.
Osney Mead, Oxford OX2 OEL, England

Hydrobiologia

Dr. W. Junk Publications
PO Box 13713, 2501 ES
The Hague, Netherlands

Journal of Aquatic Plant Management (previously Hyacinth Control Journal)

Aquatic Plant Management Society, Inc.
PO Box 16
Vicksburg, MS 39180-0016

Journal of Environmental Quality

American Society of Agronomy
677 S. Segoe Rd.
Madison, WI 53711

Journal of Freshwater Ecology

Oikos Publications, Inc.
PO Box 2558
La Crosse, WI 54601

Journal of Pesticide Science

Pesticide Science Society of Japan
Tokyo University of Agriculture
Department of Agricultural Chemistry
Tokyo 156, Japan

Limnology and Oceanography

American Society of Limnology and Oceanography, Inc.
Great Lakes Marine and Water Center
2200 Bonisteel Blvd.
Ann Arbor, MI 48109

New Zealand Journal of Marine and Freshwater Research

Department of Science and
Industrial Research
Scientific Information Division
PO Box 9741
Wellington, New Zealand

Pesticide Science

Blackwell Scientific Publications, Ltd.
Osney Mead, Oxford OX2 OEL, England

Water Research

Pergammon Press, Ltd.
Headington Hill Hall
Oxford OX3 OBW, England

Water Resources Bulletin

American Water Resources Association
St. Anthony Falls Hydraulic Laboratory
Mississippi River at 3rd Ave SE
Minneapolis, MN 55414

Weed Research

Blackwell Scientific Publications, Ltd.
Osney Mead, Oxford OX2 OEL, England

Weed Science (previously Weeds)

Weed Science Society of America
309 W. Clark St.
Champaign, IL 61820

MINOR REFERENCES

American Journal of Botany

Botanical Society of America
Ohio State University
Department of Botany
1735 Neil Ave., Columbus, OH 43210

Applied and Environmental Microbiology

American Society for Microbiology
1913 I St. NW
Washington, DC 20006

Ecology

Ecological Society of America
Arizona State University
Center for Environmental Studies
Tempe, AZ 85287

Environmental Pollution, Series A

Elsevier Applied Science
Publications, Ltd.
22 Rippleside, Commercial Est.
Ripple Rd.
Barking, Essex, IG11 OSA, England

Environmental Science and Technology

American Chemical Society
1155 Sixteenth St. NW
Washington, DC 20036

Journal of Agriculture and Food Chemistry

American Chemical Society
1155 Sixteenth St. NW
Washington, DC 20036

Journal of Chemical Ecology

Plenum Publishing Corp.
233 Spring St.
New York, NY 10013

Journal of Ecology

Blackwell Scientific Publications, Ltd.
Osney Mead, Oxford OX2 OEL, England

Journal of Environmental Science and Health

Marcel Dekker, Inc.
270 Madison Ave.
New York, NY 10016

Pesticide Biochemistry and Physiology

Academic Press, Inc.
111 Fifth Ave.
New York, NY 10003

Soil Science Society of America Journal

Soil Science Society of America
677 S. Segoe Rd.
Madison, WI 53711

Water, Air, and Soil Pollution

D. Reidel Publishing Co.
Voorstraat 479-483, PO Box 17
3300 AA Dordrecht, Netherlands